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## THE CONSTANTS OF COLOR.

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THE tints produced by Nature and art are so manifold, often so vague and indefinite, so affected by their environment, or by the illumination under which they are seen, that at first it might well appear as though nothing about them were constant; as though they had no fixed properties which could be used in reducing them to order, and in arranging in a simple but vast series the immense multitude of which they consist.

Let us examine the matter more closely. We have seen that when a single set of waves acts on the eye a color-sensation is produced, which is perfectly well defined, and which can be indicated with precision by referring it to some portion of the spectrum. We have also found that, when waves of light having all possible lengths act on the eye simultaneously, the sensation of white is produced. Let us suppose that by the first method a definite color-sensation is generated, and afterward by the second method the sensation of white is added to it: white light is added to or mixed with colored light. This mixture may be accomplished with an ordinary spectroscope, by removing the scale from the scale-telescope, and replacing it by a vertical slit, as indicated in Fig. 1, which is a view from above. Then, if white light be allowed to enter this slit, it will be reflected from the surface of the prism into the observing-telescope, and we shall find that the spectrum is crossed by a vertical band of white light. By moving with the hand the scale-telescope, this white band may be made to travel slowly over the whole spectrum, and furnish us with a series of mixtures of white light with the various prismatic tints. (*See* Fig. 2.) The general effect of this proceeding will be to diminish the action of the colored light; the resultant light will indeed pre-

sent to the eye more light, but it will appear paler; the color-element will begin to be pushed into the background. Conversely, if we now should subject our mixture of white and colored light to analysis by a second spectroscope, we should infallibly detect the presence of the white as well as of the colored light; or, if no white light were present, that would also be equally apparent.

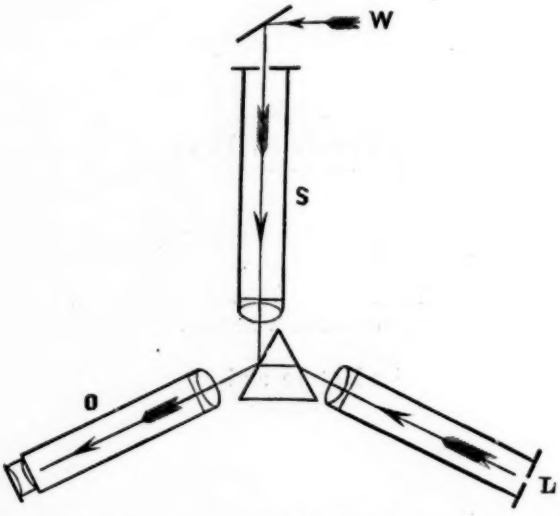


FIG. 1.—*O* is the observing-telescope; *S* the scale-telescope; *L* the source of light which furnishes the spectrum; *W* the white light which is projected on the spectrum.

Taking all this into consideration, it is evident that when a particular color is presented to us we can affirm that it is perfectly pure, viz., entirely free from white light; or that it contains mingled with it a larger or smaller proportion of this foreign element. This furnishes us with our first clew toward a classification of colors: our pure standard colors are to be those found in the spectrum; the colored light coming from the surfaces of natural objects, or from painted surfaces, we must compare with the tints of the spectrum. If this is done, in almost every case the presence of more or less white light will be detected; in the great majority of instances its preponderance over the colored light will be found quite marked. To illustrate by an example: If white paper be painted with vermilion, and compared with a solar spectrum, it will be found that it corresponds in general tone with a certain portion of the red space; but the two colors never match perfectly, that from the paper always appearing too pale. If, now, white light be added to the pure spectral tint, by reflecting a small amount of it into the observing-telescope, it will become possible to match the two colors, and, if we know what proportion of white light has been added, we can afterward say that the light reflected

from the vermilion consists, for example, of eighty per cent. of red light from such a region of the spectrum, *plus* twenty per cent. of white light. If we set the amount of light reflected by white paper as 100, then a surface painted with "emerald-green" reflects about eight parts of white light; artificial ultramarine, two or three parts; red lead, seven or eight, etc. Some white light is always present; its general effect is to soften the color and reduce its action on the eye; when the proportion of white is very large, only a faint reminiscence of the original hue remains; we say the tint is greenish-gray,

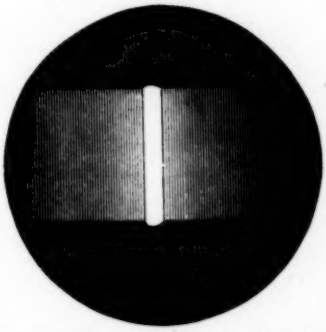

FIG. 2.—SPECTRUM CROSSED BY BAND OF SUPERIMPOSED WHITE LIGHT.

bluish-gray, or reddish-gray. The specific effects produced by the mixture of white with colored light will be considered in a future chapter; it is enough for us at present to have obtained an idea of one of the constants of color, viz., its purity. The same word, it may be observed, is often used by artists in an entirely different sense: they will remark of a painting that it is noticeable for the purity of its color, meaning only that the tints in it have no tendency to look dull or dirty, but not at all implying the absence of white or gray light.

Next let us suppose that in our study of these matters we have presented to us for examination two colored surfaces, which we find reflect in both cases eight-tenths red light and two-tenths white light. In spite of this the tints may not match, one of them being much brighter than the other, containing, say, twice as much red light and twice as much white light; having, in other words, twice as great brightness or luminosity. The only mode of causing the tints to match will be to expose the darker-colored surface to a stronger light, or the brighter surface to one that is feebler. It is evident, then, that brightness or luminosity is one of the properties by which we can define color; it is our second color-constant. This word luminosity is also often used by artists in an entirely different sense, they calling color in a painting luminous simply because it recalls to the mind the impression of light, not because it actually reflects much light to

the eye. The term bright color is sometimes used in a somewhat analogous sense, but the ideas are so totally different that there is little risk of confusion.

The practical determination of the second constant is possible in a great many cases; it presents itself always in the shape of a rather troublesome photometric problem, capable of a more or less accurate solution. The relative brightness of the colors of the solar spectrum is one of the most interesting of these problems, as its solution would serve to give some idea of the relative brightness of the colors, which, taken together, constitute white light. Quite recently a set of measurements were made in different regions of the spectrum by Vierordt, who denoted the points measured by the fixed lines, as is usual in such studies.[1] The following table will serve to give an idea of his results:

| Color. | Degree of Luminosity. |
|---|---|
| Dark red | 800 |
| Red | 4,930 |
| Red, slightly orange | 11,000 |
| Orange red | 27,730 |
| Orange | 69,850 |
| Yellow | 78,910 |
| Green | 30,330 |
| Cyan blue | 11,000 |
| Blue | 4,930 |
| Ultramarine blue | 906 |
| Violet | 359 |
| " | 131 |
| " | 58 |
| " | 9 |

These measurements were made on a spectrum obtained by a glass prism, which, as has been mentioned in a previous chapter, contracts the red, orange, and yellow spaces unduly, and hence increases their illumination disproportionately. It is to be hoped that a corresponding set of measurements will soon be made on the normal spectrum, furnished by a ruled plate. If we should multiply the luminosity of the colors in either kind of spectrum by their extent or areas, we should obtain measures of the relative amounts of these several tints in white light.

By the simple method of rotating disks we can very roughly determine the second constant in the case of a colored surface, for example, of paper tinted with vermilion. A circular disk, about six inches in diameter, is cut from the paper, and placed on a rotation apparatus, as indicated in Fig. 3. On the same axis is fastened a double disk of black-and-white paper, so arranged that the proportions of black-and-white can be varied at will. When the whole is set in rapid rotation, the color of the vermilion paper will of course not

[1] C. Vierordt, *Poggendorf's Annalen*, Band cxxxvii., S. 200.

be altered; but the black-and-white will blend into a gray. This gray can be altered in its brightness till it *seems* about as luminous as the red. If we find, for example, that with the disk three-quarters black and one-quarter white an equality appears to be established, we conclude that the luminosity of our red surface is twenty-five per cent. of that of white paper. This is of course based on the supposition that the black paper reflects no light; it actually reflects from two to five per cent., the reflecting power of white paper being put at 100. The results thus obtained are always inexact, and the same ob-

FIG. 3.—COLORED DISK WITH SMALL BLACK-AND-WHITE DISK.

FIG. 4.—COLORED DISK WITH SMALL BLACK-AND-WHITE DISK IN ROTATION.

server will often obtain different results on different days, though those of a single day may agree pretty well among themselves. In the appendix to this chapter, a peculiar photometer will be described, which has been contrived by the author for the purpose of comparing more accurately together the relative luminosity of different colored surfaces, or that of colored and white surfaces.

But to resume our search for color-constants. We may meet with two portions of colored light, having the same degree of purity and the same apparent brightness, which nevertheless appear to the eye totally different; one may excite the sensation of blue, the other that of red; we say the *tones* are entirely different. The *tone* of the color is, then, our third and last constant, or, as the physicist would say, the degree of refrangibility, or the wave-length of the light. It has in a previous chapter been shown that the spectrum offers all possible tones except the purples, well arranged in an orderly series; and the purples themselves can be produced with some trouble, by causing the blue or violet of the spectrum to mingle in certain proportions with the red. Rutherford's automatic six-prism spectroscope can very conveniently be employed for the determination of the tone. (*See* Fig. 5.) A peculiar eye-piece is to be used, which isolates a little slice of the spectrum in its upper half, as indicated in Fig. 6. In the lower half of the field the fixed lines are seen, and the tone selected as match-

ing the color under examination can be located by their aid. Afterward, if it is considered desirable, white light can be added to the spectral tint, till it is subdued sufficiently to render exact comparison possible.

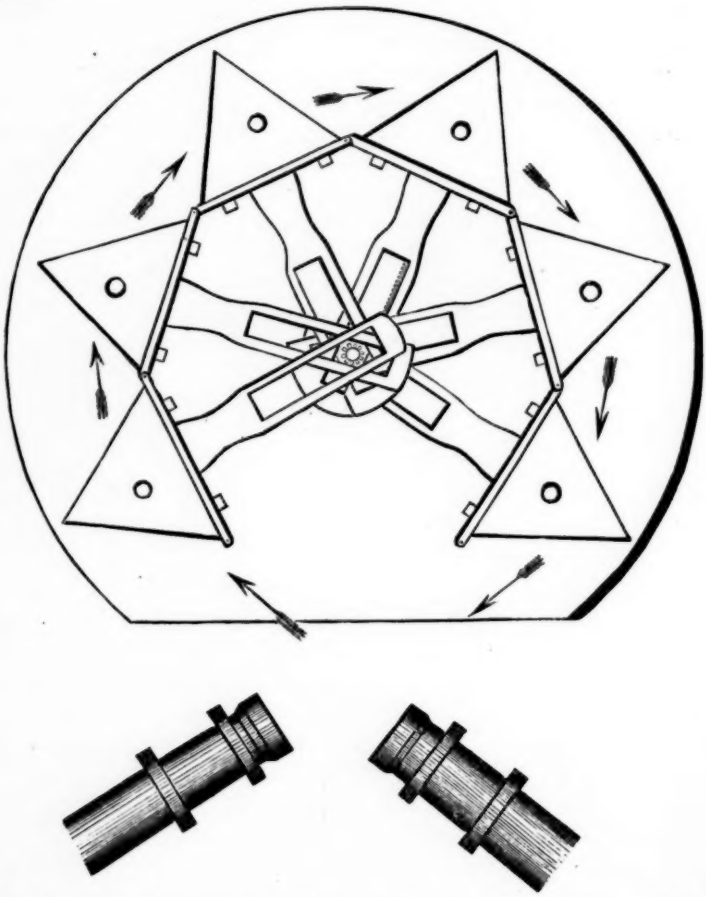

FIG. 5.—FAC-SIMILE OF RUTHERFORD'S DRAWING OF SIX-PRISM SPECTROSCOPE.—(*American Journal of Sciences and Arts*, 1865.)

The experimental determination of the color-constants is beset with a considerable amount of difficulty, even in the simplest cases, such as cardboards covered with pigments. The best mode of proceeding appears to be to call the luminosity of white cardboard 100, and then to determine photometrically the comparative luminosity of the colored cardboards. The measurement of the amount of white light reflected along with the colored is still more troublesome, and the result likely to be somewhat less exact, while the determination of the tone, or third constant, is moderately easy under favorable circumstances. One of the uses of such determinations is the pro-

duction of a set of standard colored disks with known constants, which can afterward be combined with each other, as well as with standard black or white disks, so as to generate at will, with ease and certainty, an immense number of tints whose constants will be known. If we make a record of the constants involved in such experiments, we can afterward reproduce the tints just as they originally were, or alter them to any desirable extent. To carry out the letter of this it will of course be necessary to view the standard disks under similar illuminations at different times, a point which can be secured with the

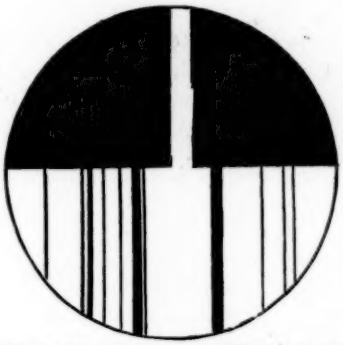

FIG. 6.—EYE-PIECE FOR ISOLATING THE TINTS OF THE SPECTRUM.

aid of the photometer above referred to. The standard disks can also be used for building up a set of standard charts, containing a vast variety of tints of known composition, arranged methodically with regard to purity, luminosity, and tone. These matters will be considered at some length in a separate chapter, and are now only hinted at as a justification for the trouble we have been at in defining the constants of color.

There is another point to be touched on in this connection. One of the most noticeable things about colors is their difference in *intensity*. Colors are intense when they excel both in purity and brightness; for it is quite evident that, however pure the colored light may be, it still will produce very little effect on the eye if its total quantity be small; and, on the other hand, it is plain that its action on the same organ will not be considerable if it is diluted with much white light. Purity and brightness, or luminosity, are, then, the factors on which intensity depends. We shall see hereafter that this is strictly true only within certain limits, and that an inordinate increase of luminosity is attended with a loss of intensity of hue.

Having defined the three constants of color, it will be interesting to inquire into the sensitiveness of the eye in these directions. This subject has lately been studied with care by Aubert, who made an extensive set of observations with the aid of colored disks.[1] It was

[1] Aubert, "Physiologie der Netzhaut," Breslau, 1865.

found that the addition of one part of white light to 360 parts of pure colored light produced a change which was perceptible to the eye; smaller amounts failed to bring about this result. It was also ascertained that mingling pure colored light with from 120 to 180 parts of white light caused it to become invisible, the hue being no longer distinguishable from white. Differences in luminosity as small as $\frac{1}{120}$ to $\frac{1}{180}$ could under favorable circumstances be perceived. It hence followed that irregularities in the illumination or distribution of pigment over a surface, which were smaller than $\frac{1}{180}$ of the total amount of light reflected, could no longer be noticed by the eye. Experiments with red, orange, and blue disks were made on the sensitiveness of the eye to changes of tone or refrangibility; thus the combination of the blue disk with a minute portion of the red disk altered its hue by moving it a little toward violet; on reversing the case, or adding a little blue to the red disk, the tone of the latter moved in the direction of purple. Similar combinations were made with the other disks. Aubert ascertained, in this way, that recognizable changes of tone could be produced by the addition of quantities of colored light as small as from $\frac{1}{100}$ to $\frac{1}{300}$ of the total amount of light involved. From such data he calculated that in a solar spectrum at least 1,000 distinguishable tones are visible. But we can still recognize these tones when the light producing them is subjected to considerable variation in brightness. Let us limit ourselves to 1,000 slight variations, which we can produce by gradually increasing the brightness of our spectrum, till it finally is ten times as luminous as it originally was. This will furnish us with a million tones, differing perceptibly from each other. If each of these tones is again varied 300 times, by the addition of different quantities of white light, it carries up the number of hues we are able to distinguish as high as 300,000,000. In this calculation no account is taken of the purples, or of colors which are very bright or very faint, or mixed with very much white light. For these it will hardly be extravagant to demand another 100,000,000; we reach thus the astonishing conclusion that the human eye under favorable circumstances is able to distinguish as many as 400,000,000 different hues!

# MODERN PHILOSOPHERS ON THE PROBABLE AGE OF THE WORLD.[1]

A SHORT time ago Sir William Thomson took occasion, at a meeting of the Geological Society of Glasgow, to make a somewhat startling statement. He said that the tendency of British popular geology was, at the time he spoke, in direct opposition to the principles of natural philosophy.

So strong an opinion expressed by the man who is, perhaps, foremost in this country in applied mathematics and natural science, naturally attracted great attention, and it is not too much to say that in the six years which have since elapsed a very great change has taken place in the views of those best able to form an opinion on the subject of Sir William Thomson's animadversions.

Whether or not we are correct in saying that such a change has actually taken place in educated public opinion, it is the object of this paper to show; but we may at least affirm at the outset, without fear of contradiction, that a very smart conflict has been raging on the subject in the scientific world. The opposing forces are the geologists and the mathematicians. There has been hard hitting on both sides, and no quarter given. Of late the mathematicians have brought up their reserve, a contingent of natural philosophers, who have done good service. The latest intelligence from the seat of war speaks of a suspension of hostilities. The mathematicians will make no concessions, but the geologists appear likely to abate somewhat of their high demands. There is even some talk of an amalgamation of the opposing armies. In plain English, there has been a dispute as to the age of the world. Geologists declared that the centuries of its duration could only be denoted by an array of figures so large as to paralyze the reasoning faculties and convey no definite impression to the mind. Other branches of science have shown cause for attributing to the solar system a limit of duration, vast indeed, but not absolutely inconceivable.

To those whose interest in such matters is literary rather than

[1] 1. "Lectures on some Recent Advances in Physical Science." By Prof. P. G. Tait, Professor of Natural Philosophy in the University of Edinburgh. 1876.

2. "On Geological Dynamics." By Sir William Thomson, LL. D., F. R. S. "Transactions of the Geological Society of Glasgow," 1869.

3. "On Geological Time." By Sir William Thomson, LL. D. "Transactions of the Geological Society of Glasgow." 1868.

4. "Sur le Ralentissement du Mouvement de Rotation de la Terre." Par M. Delaunay. Paris, 1866.

5. "Climate and Time." By James Croll. "H. M. Geological Survey of Scotland." London, 1875.

6. "Principles of Geology." By Sir Charles Lyell. Fourteenth edition. London, 1875.

scientific, the progress of such a controversy is often very entertaining. It is true that the actual battles take place in places beyond our ken, generally at meetings of scientific societies, where the orators have it all their own way and confound their adversaries—till the opposition society meets. But though the philosophers retire for fighting purposes, and do battle in the clouds with weapons, phrases, and formulæ, that we cannot understand, they always come down again to earth to proclaim their victories or palliate their defeats. Once they come down, and we catch them with pens in their hands, the outsiders have their turn.

It is not, however, in the great books of Darwin, Huxley, Lyell, Helmholtz, Tait, or Thomson, that we may seek food for amusement. In these works every thought is in full dress and every phrase decorous. But there is another sort of literature in which we see the great men, so to speak, with their coats off. The "Proceedings" of the learned societies where the real fighting goes on are full of entertainment. Students of human nature need no further proof that, though every man may not be a philosopher, every philosopher is certainly a man. With what frank enjoyment they fight! With what irony—what sarcasm they annihilate their foes! It must, however, be confessed that sarcasm is not, as a rule, the strong point of the learned. The editor of a northern newspaper of our acquaintance was one day speaking in terms of praise of his sub-editor: "The brilliancy of yon young man," said he, "is surprising; the facility with which he jokes amazes me. I, myself, am in the habit of joking, but I joke with difficulty." We have observed the same peculiarity among other learned persons. They joke, but not with ease.

Most of the books which we have prefixed to this paper contain their authors' thoughts polished *ad unguem*. It would not be fair to judge of the opinions of the scientific persons we quote by any other standard than that which they have themselves carefully prepared; but yet we cannot refrain from entertaining a preference for the rough-and-ready, hard-hitting pamphlets, lectures, "proceedings," inaugural addresses, and the like, from which, almost without exception, these works have been compiled. For example, Mr. Croll's work on "Climate and Time" is everything which a scientific work should be that requires deep research and laborious thought, combined with the boldest generalization; but it is a digest of some five or six and thirty papers contributed to scientific magazines and periodicals during several years. Mr. Croll gives a list of his papers at the end of his volume. But though it is most convenient to see the whole before us at a glance, and to have them all under our hand or on the library-shelf, yet we acknowledge that while thinking over Mr. Croll's volume, for the purposes of this review, we found ourselves again and again going back to the pages of the *Reader* and the *Philosophical Magazine*, in which we first made acquaintance with them. It may be prejudice

in favor of old acquaintances, but we liked them better before. Digressions, perhaps, are cut out; some little rash speculation quietly withdrawn; some hit at an opponent suppressed; but they do not always command the same ready assent, or appear so interesting as they did in their old form.

These remarks do not apply to Prof. Tait. His lectures now before us, from their nature, belong to the class of composition for which we avow our predilection. They were delivered *extempore* to a scientific audience, and printed from short-hand notes. They lose nothing of their vigor, to use an expression of Lord Macaulay, by translation out of English into Johnsonese. We are allowed to seize the thought in the making, and, if it loses anything in grace, the loss is more than counterbalanced by power.

Those who wish thoroughly to understand the subject of this paper should study Prof. Tait's lectures on the souces of energy, and the transformation of one sort of energy into another. Matthew Arnold's phrase, "let the mind play freely round" any set of facts of which you may become possessed, often recurs to the mind on reading these papers. There is a rugged strength about Prof. Tait's *extempore* addresses, which taken together with their encyclopedic range, and the grim humor in which the professor delights, makes them very fascinating. They have another advantage. Men not professionally scientific find themselves constantly at a loss how to keep up with the rapid advance which has characterized recent years. One has hardly mastered a theory when it becomes obsolete. But in Prof. Tait we have a reporter of the very newest and freshest additions to scientific thought in England and on the Continent, with the additional advantage of annotations and explanations by one of the most trustworthy guides of our time.

We propose to discuss the books and papers whose titles are prefixed to this article, in so far as they throw fresh light on the probable length of time during which the solar system may be supposed to have existed. It is but in recent times that any materials have been amassed for forming an opinion on the subject. Before the end of the last century geology hardly existed as a science; an inquiry as to the age of the world would have been unhesitatingly answered by the assertion that the earth was created in six days, 4,004 years before the birth of Christ. Though further research has shown that the sacred text bears no such interpretation, those copies of the "Authorized Version of the Bible" which are enriched with notes and marginal references still keep up the formal assertion.

A story is told in Brydone's "Tour in Sicily" which will serve to recall the state of public opinion on the subject of chronology at the end of the last century. The Canonico Recupero, a Sicilian priest, was Brydone's guide when he explored Mount Etna. Recupero (who afterward wrote a history of his native mountain) told the traveler

that he had been vastly embarrassed by the discovery that many strata of lava, each covered deeply with earth, overlaid each other on the mountain-side. "Moses," said he, "hangs like a dead weight upon me, for I have not the conscience to make the mountain so young as that prophet makes the world." "The bishop," adds Brydone, "who is strenuously orthodox—for it is an excellent see—has warned him to be on his guard, and not to pretend to be a better historian than Moses."

The worthy Bishop of Catania was not alone in his views. Nearer home it was the generally-received opinion that to doubt the literal accuracy of the chronology supposed to be involved in the Mosaic account was a grave impiety. The poet Cowper, mildest of men, became fiercely satirical under the provocation of geology. Though few people read "The Task" nowadays, the lines will no doubt be remembered:

> "....Some drill and bore
> The solid earth, and from the strata there
> Extract a register by which we learn
> That He who made it, and revealed its date
> To Moses, was mistaken in its age."

Fortunately, it is no longer considered impious to try and "extract a register" from the earth. Those who were inclined to be afraid that the Mosaic record would be discredited have long since laid aside their fears. It has been found that, far from being upset by scientific inquiry, the Bible account of the Creation accords in a very remarkable manner with modern discoveries; and long before Max Müller put the feeling into words, it was felt that only "by treating our own sacred books with neither more nor less mercy than the sacred books of other nations, they could retain their position and influence."

When once the plunge was made, it was soon found, as might have been expected, that the fault was not in the oracle, but in the interpretation; and it is very remarkable in how many and unexpected directions the testimony of Moses has been strengthened by the criticism, not always friendly, which it has received. Of course, when the anciently-accepted date of the Creation was proved to be incorrect, and chronology was, as it were, thrown open to the public, there was nothing to prevent philosophers from allowing the freest scope to their imagination. In proportion as the six thousand years formerly assigned as the age of created matter was too small, the reaction of opinion claimed for it an antiquity which workers in other branches of physics feel it impossible to concede; and at the present moment there is among scientific men a revolt against the extreme views of the geologists. The latter affirmed with truth that creation in six solar days was demonstrably untrue, not because God could not create the world at a stroke, but because the world bears ample evidence that he did not so exercise his power. It was inconsistent

alike with reasoning from probability or the investigation of facts. In all the operations of Nature as they unfolded themselves before our eyes God worked by law—by the process of slow development—by means beautifully simple, and involving no violence and no haste, yet irresistible. There was abundant evidence that these causes had been at work for thousands—perhaps millions—of years before the date of the supposed miracle. Beginning from the present age, the time was calculated that each development would require, till the united ages of all amounted to the enormous sum of three hundred millions of years.

Modern English geology holds that all geological changes have been effected by agents now in operation, and that those agents have been working silently at the same rate in all past time; that the great changes of the earth's crust were produced, not by great convulsions and cataclysms of Nature, but by the ordinary agencies of rain, snow, frost, ice, and chemical action. It teaches that the rocky face of our globe has been carved into hill and dale, and ultimately worn down to the sea-level, not only once or twice, but many times over during past ages; that the principal strata of the rocks—hundreds, and even thousands, of feet thick—have been formed on ocean-floor-beds by the slow decay of marine creatures and matter held in solution by the waves; that every part of the earth has been many times submerged, and has again been lifted into the air. This slow rising and sinking of the ground is an axiom of the geological creed. We are told that it is now going on, and that there are large areas of subsidence and of elevation on the surface of the globe. But when we consider the slow rate at which that oscillation is now proceeding, and argue back from the known to the unknown, we are landed in conclusions as to the length of time required for geological changes which the opponents of the theory declare to be absolutely inadmissible.

Sir William Thomson, Prof. Tait, and Mr. Croll, argue the question as one of geological dynamics. They find reason, in recent discoveries of science, to assert that the sun and the earth, from their physical condition, cannot possibly have existed for the enormous length of time supposed. Playfair, the founder of what is called the Uniformitarian school of geology, declares, on the other hand, that in the existing order of things there is no evidence either of a beginning or of an end. "In the planetary motions," he says, "where geometry has carried the eye so far both into the future and the past, we discover no mark either of the commencement or the termination of the present order. The author of Nature has not given laws to the universe, which, like the institutions of men, carry in themselves the elements of their own destruction." This was a bold assertion: it was adopted with very little limitation by Sir Charles Lyell and the later geologists—his disciples and contemporaries. Indeed, if they admitted any limitations at all, they placed the origin of the world so many

hundreds of millions of years ago that the figures convey no practical idea to the mind, and amount in effect almost to what a distinguished geologist calls "eternity *a parte ante*."

The principal grounds upon which scientific opinion has recently declared itself in favor of limited periods for the duration of the solar system are based, first, on the belief that the earth is cooling—if not rapidly—at such a rate as to make it impossible that it should have existed for very many millions of years; secondly, because there is reason to believe that the earth is not now rotating on her axis with the same rapidity as in former ages, and that, as her shape would have been different if, at the time she was in a molten state, she had been rotating more rapidly than now, she has not been rotating so long as has been supposed; thirdly, because the sun is parting with caloric at such a rate as to make it certain that he could not have continued to radiate heat at the same rate for more than a few millions of years; and lastly, because the changes in the earth's crust, stupendous and varied as they are, could have been, and probably were, accomplished in the course of much shorter periods than popular geology has hitherto considered possible.

It will, of course, be understood that any inquiry as to the date of creation must necessarily have relation only to the solar system—the sun, that is, and the planets which accompany the earth in its orbit round the central luminary.

The investigation is of necessity thus narrowed, because we have not, and cannot expect to have, any definite information as to the age of the rest of the visible universe. The stars are forever beyond our ken. If the spectroscope can bring intelligence of their component elements, it is as much as we can hope to attain; for their immeasurable distance effectually removes them from investigation. No action of gravity emanating from those distant luminaries affects the internal economy of the solar system. In the vast eternity of space the sun and his attendant satellites are altogether alone.

It is difficult to gaze upon the thousands of stars that brighten the night with their radiance, and yet realize our entire isolation. The solar system, with the radius of its orbit stretching from the sun to farthest Neptune, is but a point in a vast solitude. No star is nearer to us than 200 millions of millions of miles.

It is difficult, in dealing with such enormous numbers, to retain a definite impression on the mind. Our powers of conception are fitted rather to the wants of common life than to a complete survey of the universe.

Perhaps an intelligent may be substituted for a merely formal assent to these numbers, if they are considered on a greatly-diminished scale. Consider the figures on the scale of one mile to 100,000,000. On that scale the sun's distance from the earth will be represented by nearly one mile. Let the sun be represented by a globe

on the top of St. Paul's Cathedral, and the earth by a little ball on the top of the clock-tower of the Houses of Parliament. The interior planets would revolve round St. Paul's as a centre; Mercury, at the distance of St. Clement's Church in the Strand; Venus, at the distance of St. Martin's Church, Trafalgar Square; Mars would be at Lambeth Bridge; Jupiter, at Walham Green; Saturn, in the middle of Richmond Park; Uranus, a little nearer the centre than Slough; Neptune, a couple of miles short of Reading. The outermost planet of the solar system, then, would on this scale revolve in an orbit comprising London and its neighborhood as far as Stevenage on the north, Chelmsford and Rochester on the east, and Horsham on the south.

On that same scale the nearest fixed star would be nearly as far away as the moon is in the actual heavens.[1]

This inconceivable remoteness shows that the sun and his satellites lie apart in space. They form one whole, interdependent on each other, but completely removed, as regards their internal economy, from the influence of any attraction outside.

There are reasons for concluding that the system, thus organized and isolated, was brought into existence by one continuous act of creative energy, and that, however long the period over which the process may have been spread, the whole solar system forms part of one creation; and though it has been sometimes thought that the earth was made by itself, and that the sun was introduced from outside space, or created where he is at a different time, the evidence is strong against such a supposition.

In the first place, the orbits of all the planets are nearly in one plane, and describe very nearly concentric circles. If, when they received the original impulse which sent them revolving round the sun, any of them had been started with a little more original velocity, such planets would revolve in orbits more elongated. If, therefore, they had been the result of several distinct acts of creation, instead of being parts of one and the same act of creation, their orbits would probably have been so many ovals, narrow and wide in all degrees, and intersecting and interfering with each other in all directions. Yet if this want of harmony had existed, even to a small degree, it would have been sufficient to destroy the existing species of living creatures, and cause to disappear all security for the stability of the solar system. If the earth's orbit were much more eccentric than it is, all living creatures would die, for the extremes

[1] On the scale of 1 mile to 100,000,000 miles:

| | Miles. | | Miles. |
|---|---|---|---|
| Mercury would be distant from the sun | 0.35 | Saturn | 8.71 |
| Venus | 0.66 | Uranus | 17.52 |
| The earth | 0.91 | Neptune | 27.43 |
| Mars | 1.39 | And α Centauri, the nearest fixed star | 206,560.00 |
| Jupiter | 4.75 | | |

of heat and cold at different periods of the year would be fatal to life. If the orbit of Jupiter were as eccentric as that of Mercury, the attraction of the larger planet would cause the smaller to change their approximately circular orbits into very long ellipses; such would be the disturbance that they would fall into the sun or fly off into remote space. The moon would approach nearer and nearer to the earth with every revolution; the year would change its character; violent heat would succeed to violent cold; the planets would come nearer and nearer; we should see them portentous in size and aspect, glaring and disappearing at uncertain intervals; tides, like deluges, would sweep over whole continents; and, finally, the fall of the moon or one of the planets to the earth would result in the absolute annihilation of both of them.

Another reason for supposing that the solar system is the result of one separate act of creation is, that all parts of it are subject to one uniform law—that of gravitation. By that law every particle of matter attracts every other particle with a force directly proportionate to its mass. This force varies as the inverse square of the distance: that is, if the attractive force of a given mass at one mile were called 1, at two miles it would be $2 \times 2 = 4$, or $\frac{1}{4}$ of 1, and so on. This law of the inverse square, as it is called, is but the mathematical expression of a property which has been imposed upon matter by the Creator. It is no inherent quality, so far as we know. It is quite conceivable that the central law might have been different from what it is. There is no reason why the mathematical fact should be what it is except the will of the Being who imposed the law. Any other proportion could equally well be expressed mathematically, and its results calculated. As an instance of what would occur if any other proportion than the inverse square were substituted as the attractive force of gravity, suppose, at distances 1, 2, 3, the attractive force had varied as 1, 2, 3, instead of the squares of those numbers. Under such a law any number of planets might revolve in the most regular and orderly manner. But under this law the weight of bodies at the earth's surface would cease to exist; nothing would fall or weigh downward. The greater action of the distant sun and planets would exactly neutralize the attractive force of the earth. A ball thrown from the hand, however gently, would immediately become a satellite of the earth, and would for the future accompany its course, revolving about it in the space of one year. All terrestrial things would float about with no principle of coherence or stability—they would obey the general law of the system, but would acknowledge no particular relation to the earth. It is obvious that such a change would be subversive of the entire structure and economy of the world. From these and similar considerations, it follows that, although other laws are conceivable under which a solar system might exist, the solar system, such as we know it, could only exist under the actual

laws which have been imposed upon its motions. And this seems entirely to exclude the idea that the various bodies of the system could have been created at different times or brought together from different parts of infinite space. We may then safely conclude that the solar system is absolutely isolated in space, and is collectively the result of one act of creation. To the solar system, therefore, our inquiry is exclusively confined.

Although the received chronology of the world has for ages rested upon the supposed authority of the Bible, the sacred text really says nothing at all upon the subject. But, though the assertions which were so long made upon its supposed authority are not really contained in the Pentateuch, it is curious to observe how exactly the words of Moses appear to fit the most recent discoveries of science. No one has supposed that we were intended to learn science from the Bible; it is, therefore, an unexpected advantage to find that its short but pregnant sentences directly support the interpretation put by modern research upon the hieroglyphics of Nature. Moses teaches, just as modern science teaches, that the starry heavens existed far back in past duration, before the creation of the earth. He describes in majestic words the "emptiness" of chaos, and the condition of affairs from which light arose. He describes the formation of the sun, and its gradual condensation into a "light-holder" to give light upon the earth, in terms that almost seem to anticipate Herschel and Laplace. Far from assigning any date to the Creation, he is content to refer it to "former duration." No date is either mentioned or implied.

The so-called chronology was derived from two lists, one extending from Adam to Noah, the other from Noah to Abraham. These lists purport to give the direct line of descent from father to son, and the age of each individual member of the genealogy at the time when the next in succession was born. As Adam was supposed to have been created six days after the commencement of the Creation, it was simple work to add up the sum and fix the age of the world. As long as the progress of physical science showed no necessity for supposing a lengthened period to elapse between the creation of the world and the creation of man, it was taken for granted, almost without discussion, that when God had created the heavens and the earth in the beginning, he at once set about the work of arranging them for the use of man; that he distributed this work over six ordinary days, and at the close of the sixth day introduced our first parent on the scene.

Nowadays, all divines, English and foreign, agree that the word employed by Moses, and translated in our Bible by "the beginning," expresses duration or time previous to creation. *Reshith*, the Hebrew word for beginning, is in the original used without the definite article. The article was expressly omitted in order to exclude the application of the word to the order of creation, and to make it signify

previous duration or previous eternity. The words of Moses, then, "In former duration God created the heavens and the earth," may mean millions of years just as easily as one. A few verses later, describing the second day of creation, Moses declares that God made the firmament and called it heaven. It is plain from this that the heavens of the first day's creation are different from the heavens of the second day; the difference of time proves a difference of subject. The heavens of the first verse were made in former duration, before the moving of the Spirit, before the creation of light; the heavens of the second day were made after the earth and after light.

Another statement made by Moses is an extraordinary anticipation of the most recent cosmological doctrines. "The earth was desolation and emptiness and darkness upon the face of the raging deep, and the Spirit of God brooding upon the face of the waters." It is now hardly doubtful that the earth was a molten sphere, over which hung, in a dense vapor, all the water which now lies upon its surface. As the crust cooled, the aqueous vapor that surrounded it became condensed into water and rested on the surface of the land. The conflicts between the waters and the fiery heat, as the crust of the earth was broken, fell in, or was upheaved, are well described by the words of Moses, "The earth was desolation and emptiness." It is curious that the great facts of the submersion of the earth and its condition of emptiness should have been thus exactly described by Moses.

We are then told that God said, "Let there be light, and there was light." Celsus, Voltaire, and a writer in "Essays and Reviews," have found it strange that there should have been light before the creation of the sun; but, according to the theory of cosmogony now almost universally received, the earth did in fact exist before the condensation of the sun. Light there would be, from the gradually-condensing mass of nebulous and incandescent matter which occupied the whole space now circumscribed by the orbit of the earth. If Moses had wished to describe the modern doctrine concerning light, he could not have done so more happily. The sun is not called "ór," light, but Maór, a place of light, just what modern science has discovered it to be. If light be not matter, but vibrations of luminiferous ether, no words could more precisely explain what must have occurred when God set in motion the undulations which produced light, and said, "Let light be." The account given of the creation of the sun very closely anticipated modern science: "Let there be light-holders in the firmament of heaven, and let them be for light-holders in the firmament of heaven to give light upon the earth . . . and the stars." When the sun began to give his light, then, for the first time, the earth's fellow-planets, the stars, began to reflect his brilliance, and became luminaries also.

"Vestiges of Creation" was one of the first books which fairly

awakened public interest in the debatable land which lies between that which is certainly known to science and that which must always defy inquiry. Before the appearance of that remarkable book, the theory that the sun and its attendant planets were produced by the condensation of a vast nebula was but little known to the unscientific world. The idea was originally entertained by Sir William Herschel, and affords one of the greatest proofs of his commanding genius. It was afterward elaborated by Laplace; but that great astronomer was himself distrustful of it, and, while he expounded the mechanical laws by which the proposed explanation could be supported, he was careful to speak of it only as an hypothesis. As time goes on, it seems probable that the saying of Arago will be accepted, and that the views of Laplace will be universally acknowledged to be "those only which, by their grandeur, their coherence, and their methematical character, can be truly considered to form a physical cosmogony."

But, though Laplace is thus credited by Arago with the origination of this grand conception, he was not its author. Sir William Herschel gave the earliest sketch of the theory. His views were expressed with so much precision, that one cannot help feeling a little jealousy for the prior right of discovery of the English astronomer. Herschel so plainly preceded Laplace, that it seems hard that Laplace should have the credit of it. Herschel began to search after nebulæ in 1779, and soon formed a catalogue comprising an enormous number of them. By degrees it dawned upon his mind that the differences he observed in them were systematic, and at length occurred the magnificent intuition that the nebulæ are stars in process of formation.

They lie in enormous numbers in every part of the heavens, and apparently in every stage of progressive development. The slow growth of worlds, extending over ages of time, cannot, of course, be watched by any single observer. No more can a single tree among the trees of a forest be so observed. But a forest contains specimens of saplings, young trees, trees of vigorous growth, and trees in decay. In like manner the heavens contain specimens of worlds in the making, from the chaotic mass of vapory matter which forms the first stage of cosmical existence to the perfect, self-luminous star. Herschel arranged them in classes showing this gradual development, and he declares that each class is so nearly allied to the next, that they do not differ so much as would the annual description of a human figure, if it were given from the birth of a child till he comes to be a man in his prime. His catalogue arranges the objects he has actually observed somewhat in the following fashion: first, patches of extensive diffused nebulosity; "milky nebulosity," with condensation; round nebulæ; nebulæ with a nucleus; and so on till he reaches stellar nebulæ, nearly approaching the appearance of stars.

The evidence grows irresistible as we read, that in these wonder-

ful objects we are gazing at works in process of formation as they lie plastic under the creative hand of the Almighty. Nor is it possible to withhold the inference—thus probably was the world we live in, and the solar system of which we form a part, evolved out of chaos.

The labors of Laplace commenced where Herschel ended. Herschel described what he saw. Laplace showed by mathematics how the known laws of gravitation could form, and probably did form, from such partially-condensed mass of matter an entire planetary system.

It is supposed that a film of vaporous matter filled up the space which is now bounded by the orbit of the outermost planet of our system. To the eye of an observer, if such there were, in a distant star such a vapor would appear like one of the numerous nebulæ which are everywhere visible in the heavens.

Laplace supposed that this nebula, extending beyond what is now the orbit of Neptune, possessed a rotatory motion round its centre of gravity, and that the parts of it which were situated at the limits where the centrifugal force exactly counterbalanced the attractive force of the central nucleus were abandoned by the central mass. Thus, as the nucleus became more and more dense under the action of gravity, were formed a succession of rings concentric with and revolving round the centre of gravity. Each ring would break up into masses which would be endued with motions of rotation, and would in consequence assume a spheroidal form. These masses formed the various planets, which, in their turn condensing, cast off in some instances their outlying rings, as the central mass had done, and thus formed the moons or satellites which accompany the planets. As each planet was in turn cast off, the central mass contracted itself within the orbit of that last formed, till, after casting off Mercury, it gathered with immense energy round its own centre and formed the sun.

Laplace's mechanical explanation does not rest only on theory. It has been experimentally shown that matter under certain conditions would exhibit phenomena similar in many important particulars to those which Laplace was led by mathematical considerations to suppose. Prof. Plateau, several years ago, tried the experiment of pouring olive-oil into alcohol and water, mixed in such proportions as exactly to equal the density of the oil. The oil thus became a liquid mass relieved from the operation of gravity, and free to take any exterior form which might be imposed by such forces as might be brought to bear upon it. The oil instantly took the form of a globe by virtue of molecular attraction. Prof. Plateau then introduced a wire into the globe of oil in such a manner as to form for it a vertical axis. The wire had on it a little disk coincident with the centre of the globular mass, and by turning the axis the oil was made to revolve. The sphere soon flattened at the poles and bulged out at the equator, thus producing on a small scale an effect which is admitted

to have taken place in the planets. The experiment has since been several times repeated. When the rotation becomes very rapid, the figure becomes more oblately spheroidal, then hollows out above and below round the axis of rotation, stretches out horizontally until finally the outside layer of oil abandons the mass and becomes transformed into a perfectly regular ring. After a little while the ring of oil, losing its own motion, gathers itself once more into a sphere. As often as the experiment is repeated the ring thrown off immediately takes the globular form. These are seen to assume at the instant of their formation a movement of rotation upon themselves, which takes place in the same direction as that of the ring. Moreover, as the ring at the instant of its rupture had still a remainder of velocity, the spheres to which it has given birth tend to fly off at a tangent; but, as on the other side, the disk, turning in the alcoholic liquor, has impressed on the liquor a movement of rotation, the spheres are carried along and revolve for some time round the disk. Those which revolve at the same time upon themselves "present the curious spectacle of planets revolving at the same time on themselves and in their orbit." Another curious result is almost always exhibited in this experiment. Besides three or four large spheres into which the ring resolves itself, there are almost always two or three very small ones which may thus be compared to satellites. The experiment presents, therefore, an image in miniature of the formation of the planets, according to the hypothesis of Laplace, by the rupture of the cosmical rings attributable to the condensation of the solar atmosphere.

Modern discoveries carry the matter on much further. Recent investigations into the doctrine of the conservation of energy have shown the generation of cosmical heat. The amount of force comprised in the universe, like the amount of matter contained in it, is a fixed quantity, and to it nothing can either be added or taken away. It is, therefore, constantly undergoing change from one form to another. If it ceases in one form it is not destroyed, it is converted. The blow of a hammer on an anvil sets a certain amount of energy in motion. The anvil stops the blow, but the force changes into heat. Hammer a nail, and it will burn your fingers. Apply a brake to a wheel, and you will stop the motion, but the force will be changed into heat, which will burn you if you touch the brake. Measure the hammered nail, and you find that it has expanded by the vibration of its particles; heat it still more, and the particles will overcome the attraction of cohesion and revolve about each other, that is, they will become molten; heat them still more, and they will assume the vaporous or gaseous form. Now, seeing that motion was convertible into heat, and heat into motion, it became an object of inquiry what was the exact relation between the two. Dr. Mayer, in Germany, and Dr. Joule, in England, set themselves to the solution of this problem. By

various experiments it was demonstrated that, every form of motion being convertible into heat, the amount of heat generated by a given motion may be calculated. If the particles of a vast vaporous mass were brought into collision from the effect of their mutual attraction, intense heat would ensue. The amount of caloric generated by the arrest of the converging motion of a nebula like the solar system would be sufficient to fuse the whole into one mass and store up a reserve of solar heat for millions of years.

Such, then, is the most probable conjecture respecting the origin of our system. We now turn to consider the grounds on which attempts have been made to fix the probable date of its creation. It will be convenient to examine the views of modern geologists on the subject, and the objections, based on recent results of physical science, which natural philosophers have adduced against their speculations.

The great representative, in late years, of British geology, is the late Sir Charles Lyell. But a few months before his death he published the new edition of his "Principles of Geology," the title of which we have placed at the head of this paper. While he lived he bestowed upon the correction of his works unwearied labor. Edition after edition was called for, and in each whole passages—sometimes whole chapters—were remodeled. A quotation from one of the earlier editions may not improbably be searched for in vain in those which subsequently left his hands; and there are not wanting instances in which an opinion, contested by competent adversaries, was quietly dropped without any formal parade. His judgment was always open to appeal, and his clear and manly intellect acknowledged no finality in matters of opinion; therefore, on matters which we know to have been brought before him, with their accompanying evidence, we may consider ourselves as possessing his final verdict. It would not be fair when quoting, as we must do, comments unfavorable to some of the conclusions at which Sir Charles Lyell arrived, to refrain from acknowledging the care with which his opinions were formed, and the candor with which they were surrendered if ever his better judgment considered them untenable. For instance, as head of the Uniformitarian school, he was exceedingly anxious that the evidence for his favorite doctrine should be duly and impartially weighed. With this view he advocated, in his "Principles of Geology,"[1] "an earnest and patient endeavor to reconcile the indications of former change with the evidences of gradual mutations now in progress."

Upon this remark Dr. Whewell[2] fell with merciless severity: "We know nothing," says he, "of causes; we only know effects. Why then should we make a merit of cramping our speculations by such assumptions? Whether the causes of change do act uniformly;

[1] Lyell, b. iv., p. 328, fourth edition.

[2] "History of the Inductive Sciences," b. viii., sec. 2, edition of 1857.

whether they oscillate only within narrow limits; whether their intensity in former times was nearly the same as it is now: these are precisely the questions which we wish science to answer us impartially and truly. Where, then, is the wisdom of 'an earnest and patient endeavor' to secure an affirmative reply?"

This was rough handling of a pet theory, or, rather, of an argument in favor of a pet theory; but that Sir Charles Lyell felt its force is shown by the fact that no trace of the appeal attacked by Whewell appears in such later editions of the "Principles" as we have consulted.

As another instance of the same spirit, the following remark was made by Dr. Hooker, the President of the Royal Society, when addressing the British Association at Norwich. He was speaking of the progress made in public estimation by the theories of Mr. Darwin. "Sir Charles Lyell," he says, "having devoted whole chapters of the first edition of his 'Principles' to establishing the doctrine of special creations, abandons it in the tenth edition. I know no brighter example of heroism, of its kind, than this, of an author thus abandoning late in life a theory which he had for forty years regarded as one of the foundation-stones of a work that had given him the highest position attainable among contemporary scientific writers."

Among eminent persons holding the geological opinions to which the name of Catastrophism has been given, the name of the late Master of Trinity must occupy a foremost place. The words in which he avows his opinion are remarkable, not only for their exquisite beauty, but because they have a peculiar significance as almost the last utterance of a great man. The passage which follows[1] occurs in the third of a series of sermons preached in the University Church at Cambridge, in 1827. But it is curious to learn, from his "Memoirs," published this year, that he again used the same words in his college chapel just before his death:

"Let us not deceive ourselves. Indefinite duration and gradual decay are not the destiny of this universe. It will not find its termination only in the imperceptible crumbling of its materials, or the clogging of its wheels. It steals not calmly and slowly to its end. No ages of long and deepening twilight shall gradually bring the last setting of the sun—no mountains sinking under the decrepitude of years, or weary rivers ceasing to rejoice in their courses, shall prepare men for the abolition of this earth. No placid euthanasia shall silently lead on the dissolution of the natural world. But the trumpet shall sound—the struggle shall come—this goodly frame of things shall be rent and crushed by the arm of its omnipotent Maker. It shall expire in the throes and agonies of some fierce convulsion; and the same hand which plucked the elements from the dark and troubled slumbers of chaos shall cast them into their tomb, pushing them aside that they may no longer stand between his face and the creatures whom he shall come to judge."

Holding these opinions, and believing as Prof. Whewell did that

[1] "Sermons in the University Church at Cambridge, 18th February, 1827."

the upheavals and subsidence of strata which characterize the earth's crust were produced suddenly, and by violent agencies, the school to which he belonged were little likely to attempt to fix a date for the creation of the world. To their minds the facts of geology gave no evidence as to time. It is, therefore, to Sir Charles Lyell and his followers that we must turn for an estimate of duration drawn from the "testimony of the rocks."

It is impossible to deny that periods of very vast duration must have elapsed while the changes took place of which we see the traces. If, for instance, we search below the sand on English shores, we find, perhaps, a bed of earth with shells and bones; under that, a bed of peat; under that, one of blue silt; under that, a buried forest, with the trees upright and rooted; under that, another layer of blue silt, full of roots and vegetable fibre; perhaps, under that, again, another old land-surface, with trees again growing in it; and, under all, the main bottom clay of the district. In any place where bowlder clay crops out at the surface—in Cheshire or Lancashire, along Leith shore near Edinburgh, or along the coast of Scarborough—it will be found stuffed full of bits of different kinds of stone, the great majority of which have nothing to do with the rock on which the clay happens to lie, but have come from places many miles away. On examining the pebbles, they will prove to be rounded, scratched, and grooved, in such fashion as to show that at some period they have been subjected to a grinding force of immense violence. Among the pebbles in the clay, and on plains far away from mountains, are found great rocks of many tons in weight. They were carried on the backs of icebergs, which, at some time, covered the now temperate regions of the earth, and were dropped by the melting ice either in the shape of pebbles, as moraines of ancient glaciers, or as bowlders stranded when the icebergs melted in the lowlands.

Such evidence points to vast periods of more than arctic winter, which must have endured for many thousand years. But in close juxtaposition with these glacial shells and pebbles lie remains which tell of tropical climates that alternated with the dreary ages of ice. Fossil plants and the remains of animals prove that all Northern Europe was once warmer than it is now; that England bore the flora and fauna of the torrid zones. Underneath London there lies four or five hundred feet of clay. It is not ice clay; it belongs to a later geological formation, and was, in fact, the delta of a great tropical river. The shells in this clay are tropical—nautili, cones, fruits, and seeds of nipa palms, now found only at Indian river-mouths; anona-seeds, gourd-seeds, acacia fruits; the bones, too, of crocodiles and turtles; of large mammals allied to the Indian tapir, and the water-hog of the Cape. All this shows that there was once, where London stands, a tropical climate, and a tropic river running into the sea. We find in it the remains of animals which existed before the Ice age.

The mammoth, or woolly elephant, the woolly rhinoceros, the cave-lion, the cave-bear, the reindeer, and the musk-ox, inhabited Britain till the ice drove them south. When the climate became tolerable again, the mammoth and rhinoceros, the bison and the lion, reoccupied our lowlands; and the hippopotamus from Africa and Spain wandered over the plains where now the English Channel flows, and pastured side by side with animals which have long since retreated to Norway and Canada.

When the ages necessary for all these changes is allowed for, we have not, even yet, got beyond the latest period into which the history of the globe has been divided. Under the tertiary deposits lies the chalk, a thousand feet in thickness, which is composed of the shells of minute animals, which must have been deposited age after age at the bottom of a deep and still ocean, far out of reach of winds, tides, or currents. Recent dredgings in ocean-depths have proved beyond a doubt that the greater part of the Atlantic Sea floor is now being covered by a similar deposit. It must have taken ages to form, and, if the geologists are right in their estimate of the slow rate of upheaval, many more ages to become elevated above the ocean-bed where it lay. Not only once, but many times, the chalk was alternately above and beneath the waves. It is separated by comparatively thin and partial deposits of sand and clays, which show that it has been at many different points in succession a sea-shore cliff. The chalk is not flat, as it must have been at the sea-bottom; it is eaten out into holes by the erosion of the sea-waves, and upon it lie flints, beds of shore-shingle, beds of oysters lying as they grew, water-shells standing as they lived, and the remains of trees. Yet, again, there lie upon the chalk sands, such as those of Aldershot and Farnham, containing in their lower strata remains of tropical life, which disappeared as the climate became gradually colder and colder, and the age of ice once more set in. Everywhere about the Ascot Moors the sands have been ploughed by the shore-ice in winter, as they lay awash in the shallow sea, and over them is spread in many places a thin sheet of ice-borne gravel. All this happened between the date of the bowlder clay and that of the New Red Sandstone on which it rests.

We need not follow the geologist through the lower systems which overlie the metamorphic rock. The Oolite contains remains of plants and animals now extinct, the most remarkable being huge reptiles; the Triassic has fossils like the Oolite; and the Permian has remains like those in the coal on which it rests. Then follow the coal-measures, the fossil remnants of tropical vegetation; the Old Red Sandstone, with fossils principally of fishes and shells; the Silurian, in which are found the earliest forms of life; and, lastly, the hard and crystalline rocks, devoid of fossils, which are supposed to be the earliest constituent mass of our planet.

Sir Charles Lyell and his followers allege that the rate at which

species of animals change is tolerably uniform. The fossils of one age differ but little from those of ages immediately preceding and following it. We must go back, he says, to a period when the marine shells differ as a whole from those now existing to form one complete period. Counting back in stages measured by changes of fossils, we have four such stages in the tertiary formations above the chalk.

Lyell saw reason to believe, on evidence which we shall presently examine, that the age of ice commenced about a million of years ago. The place of this age of ice among the series of fossil-changes is easily marked, and so he concludes that each of his four periods above the chalk "would lay claim to twenty millions of years." We must allow Sir Charles to work up to his stupendous conclusion in his own words:

"The antecedent Cretaceous, Jurassic, and Triassic formations would yield us three more epochs of equal importance to the three Tertiary periods before enumerated, and a fourth may be reckoned by including the Permian epoch with the gap which separates it from the Trias. In these eight periods we may add, continuing our retrospective survey, four more, namely, the Carboniferous, Devonian, Silurian, and Cambrian; so that we should have twelve in all, without reckoning the antecedent Laurentian formations which are older than the Cambrian. . . . If each, therefore, of the twelve periods represents twenty millions of years on the principles above explained, we should have a total of two hundred and forty millions for the entire series of years which have elapsed since the beginning of the Cambrian period."

Eighty millions since the lower tertiary formation, one hundred and sixty millions since the formation of the coal-measures, and two hundred and forty millions since the beginning of the Cambrian period! And beyond that inconceivable antiquity lie the whole range of the primary rocks which contain no fossils.

Mr Darwin[1] assigns to the world even a greater age. "In all probability," he says, "a far longer period than three hundred millions of years has elapsed since the latter part of the secondary period." Other geologists exceed even this estimate. Mr. Jukes, for instance, after referring to this passage, in which Mr. Darwin has given an estimate of the length of time necessary for wearing down the space between the North and South Downs, declares it is just as likely that the time which actually elapsed since the first commencement of the erosion, till it was nearly as complete as it now is, was really a hundred times greater than his estimate, "or *thirty thousand millions of years!*"

To any one but a professed geologist, it would almost seem as if these ideas of geological periods had been framed on the principle which guided Mr. Montague Tigg in fixing the capital of the Anglo-Bengalee Disinterested Loan and Life-Insurance Company. "What," asked the secretary, "will be the paid-up capital according to the

[1] "Origin of Species," edition of 1859, p. 287.

next prospectus?" "A figure of two," says Mr. Tigg, "and as many naughts after it as the printer can get into the same line."

It is hard for imagination to compass the meaning of a million, and, when that number is multiplied by hundreds, the effort is altogether beyond us. But we need not dwell on this consideration; we turn at once to the practical comments made by physical science on these and such-like opinions. The first is founded on the secular cooling of the earth.

If a red-hot ball be taken from a furnace, it begins at once to part with heat at a certain definite rate. As it becomes colder it cools more and more slowly. From the known laws of heat it is quite possible roughly to approximate to the period during which the earth has been habitable for animals and plants such as we now find upon it. Whenever a body is hotter at one part than at another, the tendency of heat is to flow from the hotter body to the colder. As the earth's crust is warmer as we go farther down, there must be a steady increase of heat from the surface to the centre, and the earth is even now losing heat at a perfectly measurable rate; therefore it is possible to calculate what was the distribution of heat a hundred thousand or a thousand thousand years ago, supposing the present natural laws to have been then in existence. According to these data, about ten millions of years ago the surface of the earth had just consolidated, or was just about to consolidate; and in the course of comparatively few thousand years after that time the surface had become so moderately warm as to be fitted for the existence of life such as we know it. If we attempt to trace the state of affairs back for a hundred millions, instead of ten millions of years, we should find that the earth (if it then existed at all) must have been liquid, and at a high white heat, so as to be utterly incompatible with the existence of life of any kind with which we are acquainted.[1]

The next argument, namely, that founded on the earth's retardation by the tidal wave, is more recondite, and the theory that there is such a retardation at all is quite of recent date. Theoretical reasons connected with mechanics caused it to be adopted, and its establishment depends on the most refined astronomical investigation.

It is one of the peculiarities of time-measurement that, from the nature of things, no two periods of time can be compared directly one with another. The standards by which we measure time are less and less precise as we recede farther into the past. To-day we have as the standard unit of duration the interval between two successive transits of a star over the cross-wires of a fixed observatory-telescope. This measure has been considered until lately as absolutely fixed and invariable. And so it is for all practical purposes; the sidereal time of any heavenly body passing the meridian on a given day in 1880

[1] "The 'Doctrine of Uniformity' in Geology briefly refuted." "Proceedings of the Royal Society, Edinburgh, December, 1865."

may be ascertained from the "Nautical Almanac" to-day, and it will be found true within one-hundredth of a second. But that throws no light on the question, What is the absolute length of an hour or a second? They are both definite fractions of a day; and a day is a revolution of the earth on its axis; no artificial measurement of such an interval can prove whether the interval itself remains from age to age unchanged. To quote Humboldt as a sure guide to the received opinions of scientific men thirty years ago,[1] "The comparison of the secular inequalities in the moon's motion, with eclipses observed by Hipparchus, or during an interval of two thousand years, shows conclusively the length of the day has certainly not been diminished by one-hundredth part of a second."

The assertion is derived from Laplace, and even now is mentioned as an unquestioned fact in the most recent astronomical text-books. Halley, it is true, in 1695, discovered that the average velocity with which the moon revolves round the earth had apparently been increasing from year to year, and this acceleration remained unexplained during more than a century. Halley compared the records of the most ancient lunar eclipses of the Chaldean astronomers with those of modern times. He likewise compared both sets of observations with those of the Arabian astronomers of the eighth and ninth centuries. The result was an unexplained discrepancy, which set all theory at defiance for a century or more. It appeared that the moon's mean motion increases at the rate of eleven seconds in a century; and that quantity, small in itself, becomes considerable by accumulation during a succession of ages. In 2,500 years the moon is before her calculated place by 1½°—enough to make a very material difference in place of visibility of a solar eclipse. Laplace at last, as Sir John Herschel says, stepped in to rescue physical astronomy from its reproach, by pointing out the real cause of the phenomenon. Laplace accounted for the apparent acceleration by showing that the motion of the earth in her orbit was disturbed by the other planets, in a manner before insufficiently appreciated, and the explanation was accepted for many years as complete and satisfactory. The acceleration was calculated to the utmost point of precision attainable in mathematics by MM. Damoiseau and Plana. Using the formulæ of Laplace, and the numbers deduced from them, it was found that the circumstances and places of ancient eclipses, as recorded by historians, were brought into strict accordance with the times and circumstances as they ought to have been if the theory were true. Laplace's explanation rests upon the fact that for many thousands of years past the orbit of the earth has been tending more and more to a perfect circle—that is, the minor axis is increasing while the major axis remains unchanged. The result is, that the average distance of the moon from the sun is greater than it was in past ages. But in proportion as the moon

[1] "Cosmos," i., 161.

is released from the sun's influence she revolves faster round the earth.

When it was seen how completely the difficulties in ancient observations were explained away by the calculations of Laplace, all doubt was considered to be at an end, and astronomers supposed that the whole truth was known. But, in 1853, it occurred to Prof. Adams to recalculate Laplace's investigations, and the result was the detection of a material error, which vitiated the whole series of observations. The results of Prof. Adams's calculations were submitted to the Royal Society [1] in a paper, the explanatory part of which is very short indeed, occupying but a couple of pages of the "Proceedings." The brief statement is followed by a corroborative sea of high mathematics, into which we have no intention of asking the reader to plunge. The result, roughly stated, was to halve the amount of acceleration calculated by Laplace, and thus to leave half of the acceleration of the moon necessary for his explanation of ancient eclipses to be found in some other way. Astronomers were now in a condition almost as bad as that from which they had been rescued by Laplace.

Adams communicated his final result to M. Delaunay, one of the great French mathematicians; and it seems to have been during the investigations which that astronomer undertook to verify the calculations of Adams that it occurred to him to inquire whether our measure of time itself remains unchanged? in other words, whether the earth itself may not be rotating more slowly, instead of the moon more quickly, than in by-gone ages? It is plain that the moon will appear to be moving more quickly round the earth, if the earth itself —which is furnishing the standard by which the moon's revolution is to be measured—is rotating more and more slowly from age to age.

Newton laid it down in his first law of motion that motion unresisted remains uniform forever; and he gave as an instance of constant motion, unaffected by any external causes, this very rotation of the earth about its axis. But M. Delaunay remembered that Kant had pointed out the resistance which the earth must incur from the tide-wave, and had even approximately calculated its amount. The tidal wave is lifted up toward the moon, and on the side of the earth opposite the moon; so that, as Prof. Tait puts it, the earth has always to revolve within a friction-brake. Adams adopted this theory of tidal friction; and, in conjunction with Prof. Tait and Sir William Thomson, assigned twenty-two seconds per century as the error by which the earth would, in the course of a century, get behind a thoroughly-perfect clock (if such a machine were possible).

It may be asked, If the earth's movement be diminishing gradually in rapidity, will it eventually stop altogether? No; if ever the earth shall so far yield to the action of the tidal wave as to rotate not more rapidly than the moon, she will present to the moon always the

[1] June 16, 1853.

same part of her surface. Then the liquid protuberance directed toward the moon will no longer be a cause of delay, and the retardation will cease. This cessation of effect, owing to the cause having ceased, appears to have actually happened with regard to the moon herself. At some time the moon's crust, and, indeed, her whole substance, was in a molten state. Enormous tides must have been produced by the attraction of the earth in this viscous mass of molten rock, and the time of the moon's rotation must have been quickly compelled, by the friction, to become identical with the time of its revolution round the earth, and now, as is well known, the moon always presents to the earth the same side of her sphere.

It being thus established that there is retardation of the earth's motion, and the amount of retardation being calculated, it remains only to inquire how the fact affects the question of the world's age. We know that the flattening at the poles and bulging at the equator is the result of rotation; from the amount of retardation it can be calculated how fast the earth was rotating in by-gone ages. Two thousand millions of years ago she would, according to such calculation, have been revolving twice as fast as at present, and the amount of centrifugal force at the equator would have been four times as great as now. If the earth, subjected to such strong centrifugal force, had been liquid or even pasty, when it began to rotate, the equatorial protuberance would have been much greater than it is. It therefore follows that she was rotating at about the same rapidity as now, when she became solid, and as the rate of rotation is certainly diminishing, the epoch of solidification cannot be more than ten or twelve millions of years ago.

A third argument for restricted periods is founded on an examination of the question, How long can the sun be supposed to have kept the earth, by its radiation, in a state fit to support animal and vegetable life? Here, as might be expected, a wider range of opinion exists.

It will be conceded at once that the age of organic life upon the earth must, of necessity, be more recent than the age of the sun. The several theories as to the way in which the sun may have derived his heat may be put aside in favor of that of Helmholtz, viz., that the sun has been condensed from a nebulous mass, filling at least the entire space at present occupied by the whole solar system. The gravitation theory of Helmholtz is now generally admitted to be the only conceivable source of the sun's heat. The opinion that it can be obtained from combustion is not tenable for a moment. The amount of heat radiated is so enormous that, if the sun were a mass of burning coal, it would all be consumed bodily in 5,000 years![1] On the other hand, a pound of coal falling on the surface of the sun

[1] To maintain the present rate of radiation it would require the combustion of 1,500 pounds of coal on every square foot of the sun's surface per hour.—Croll, 346.

from an infinite distance would produce 6,000 times more heat from concussion than it would generate by its combustion. An idea of the amount of energy exerted by one pound weight falling into the sun will be conveyed by stating that it would be sufficient to hurl the Warrior, with all its stores, guns, and ammunition, over the top of Ben Nevis![1] But, if we accept gravitation as the source of energy, we accept a cause, the value of which can be mathematically determined with very considerable accuracy.

The amount of heat given off by radiation in a year[2] is known; the total amount of work performed by gravitation in condensing a nebulous mass to an orb of the sun's present size is known. The result is, that the amount of heat thus produced by gravitation would suffice for about twenty millions and a quarter of years. This is on the assumption that the nebulous matter composing the sun was originally cold, and that heat was generated in it by the process of condensation only. It is, however, quite conceivable that the nebulous mass possessed a store of heat previous to condensation, and that the very reason why it existed in the gaseous condition was that its temperature was excessive. The particles composing it would have had a tendency, in virtue of gravitation, to approach one another if they had not been kept apart by the repulsive energy of heat; it is not, then, unreasonable to suppose that the attenuated and rarefied mass was vaporous by reason of heat, and began to condense only when its particles began to cool. By the known laws under which heated gases condense, the amount of heat originally possessed by the gas bears a definite and known proportion to the amount of heat generated by condensation; and, on the assumption that the analogy holds good in the case of the sun, which holds in the condensation of other heated gases, nearly fifty millions of years' heat must have been stored up in the mass as original temperature. This, added to the twenty and a quarter millions which resulted from gravitation, gives rather more than seventy millions of years' sun-heat.

As, however, this quantity gives the total amount of heat given out by the mass since it began to condense, the earth could not have had an independent existence till long after that time. The sun must have had time to condense from its outer limits as a nebula, to within

[1] The velocity with which a body falling from an infinite distance would reach the sun would be equal to that which would be generated by a constant force equal to the weight of the body at the sun's surface operating through a space equal to the sun's radius. One pound would at the sun's surface weigh about twenty-eight pounds. Taking the sun's radius at 441,000 miles, the energy of a pound of matter falling into the sun from infinite space would equal that of a 28-pound weight descending upon the earth from an elevation of 441,000 miles, supposing the force of gravity to be as great at that elevation as it is at the earth's surface. It would amount to upward of 65,000,000,000 foot-pounds.

[2] The total amount radiated from the whole surface of the sun per annum is $8{,}340 \times 10^{30}$ foot-pounds.—Croll, 346.

the limit of the earth's orbit, before that separate existence could begin; for before then the earth must have formed part of the fiery mass of the sun. This calculation, like the others, falls short by nearly two hundred millions of years of the period estimated by Sir Charles Lyell for the commencement of life upon the earth.

But it would not be satisfactory to see a theory upset, if with the theory the means of accounting for observed facts were also destroyed. One great reason which weighs with geologists in assigning an almost incalculable age to the earth is, that among the fossils of the latest glacial epoch there are found the remains of tropical plants and animals, deposited in alternate strata with the remains of temperate climates, and this not once, but many times over. A hot climate prevailed at one time, and the earth became peopled with the flora and fauna appropriate to those conditions: after a lapse of many ages, the land subsided, and became the bed of the ocean; a vast period of upheaval then ensued, and dry land once more appeared: the climate gradually changed and ice set in: after ages more there was another slow subsidence, another equally slow upheaval, and another change of climate; and so on without end. Seeing the slow way in which the land sinks or is upheaved nowadays, it naturally appeared that no conceivable lapse of time could be enough to explain that which had obviously taken place.

Mr. Croll, however, has recently afforded an explanation at once beautiful, simple, and complete. About the facts to be accounted for there can be no doubt. The land has been many times under the sea, and the most violent changes of climate have succeeded one another. Mr. Croll's explanation is partly astronomical, and partly rests on geological dynamics. The heat of the sun is great in proportion to his distance from the earth. This distance is greater at one time of the year than another. The orbit of the earth is not quite circular, but its eccentricity varies slowly from century to century. It is just now very small, and the summer of the northern hemisphere happens when the earth is at its greatest distance from the sun. Both these circumstances tend to produce in Europe a moderate climate. But the longitude of the perihelion, as this state of things is called, is constantly changing, and the line joining the solstices moves round the orbit in about twenty-one thousand years. It follows that every ten thousand years, or thereabouts, the winter of the northern hemisphere will occur when the earth is at its farthest from the sun; and, if at that time the earth's orbit is very eccentric, the two causes combined will produce a very severe climate. Eleven thousand years hence the northern hemisphere will be nearest to the sun in summer, and farthest from him in winter. Now, if, when that state of things occurred, the eccentricity of the earth's orbit happened to be very great—if the earth in winter-time was at a part of her orbit several millions of miles farther from, and in summer-time was very much nearer, the

sun than she is now, the climate of the northern hemisphere would be very different from what it is.

One such period of great eccentricity occurred about two million five hundred thousand years ago. Fifty thousand years later there was another. Again, eight hundred and fifty thousand years ago there was a third, and two hundred thousand years ago a fourth. Those periods were characterized by cold such as we have no conception of. More than arctic winter lingered far on into the spring, and unmelted ice of one year accumulated through the next, till from the pole to the south of Scotland the earth was covered with a vast ice-cap, probably several miles in thickness.

Now, in Europe and America, wherever in fact any records are left of the glacial epoch, it is remarked that a general subsidence of the land followed closely on the appearance of the ice. This fact led certain geologists to conclude that there was some physical connection between the two phenomena, and Mr. Jamieson suggested to the Geological Society that the crust of the earth might have yielded under the enormous weight of the ice. Mr. Croll, however, gives a different explanation; and the more it is understood the more it appears to gain ground with those capable of forming an opinion. He says that the surface of the ocean always adjusts itself in relation to the earth's centre of gravity, no matter what the form of the earth happens to be. If a large portion of the water of the ocean were formed into solid ice, and placed round the north pole, its weight would naturally change the centre of gravity of the earth. The centre would be changed a little to the north of its former position. The water of the ocean would then forsake its old centre, and adjust itself with reference to the new. The surface of the ocean will therefore rise toward the north pole, and fall toward the south. The land will not sink under the sea, but, what amounts to the same thing, the sea will rise upon the land. The extent of submergence will be in proportion to the weight of the ice.

It is easy to see that glaciation would not be contemporaneous on both hemispheres. One hemisphere would be covered with ice and snow, while the other would be enjoying a perpetual spring. A glacial epoch resulting from the eccentricity of the earth's orbit would extend over a period of a hundred thousand years. But, for the reason given above, the glaciation would be transferred from one hemisphere to another every ten thousand years. A glacial epoch extending over a hundred thousand years would therefore be broken up into several warm periods. The warm period in one hemisphere would coincide with the cold one in the other, and there would be elevation of the land during the warm period and subsidence during the cold.

This cause would be quite sufficient to effect the alternate upheaval and depression. During the successive ages that each pole alternately was subjected to glaciation, the winter ice, unmelted by the brief sum-

mer, would accumulate till a cap many thousand feet thick formed at the pole, and would ultimately spread far down into what is now the temperate zone. If such an ice-cap were only equal in density to 1,000 feet of earth, accumulated, say, on the north side of the globe, the centre of gravity would be shifted 500 feet to the north; and as the ocean would accommodate itself to the centre there would be a subsidence at the north pole equal to 500 feet. But this is not all, for at the time the ice-sheet was forming on the northern hemisphere, a sheet of equal size would be melting on the southern. This would double the effect, and produce a total submergence of 1,000 feet at the north pole and a total elevation of 1,000 feet at the south pole.

It is clear that all the upheavals and submergences of land which have so impressed geologists with the immensity of time required for their execution can thus be accounted for within periods, stupendous indeed if compared to historical time, or even to the duration of man on the earth, but still conceivable by human imagination. The nightmare of subsidence and emergence need no longer oppress the geologist. He has only to remark surface-changes and see how far forces now at work are capable of effecting them, and, if so, how long they would take. The discovery of Mr. Croll upsets the whole scale of geological time. Sir Charles Lyell was quite right in saying that the earth could not have subsided and emerged from the sea half a dozen times, in less than a million of years, if it sank or rose in the leisurely manner which has characterized it in recent times: consequently he could not accept as "the glacial epoch" the most recent period of great eccentricity. He was obliged to go back to the next, which happened nearly a million years ago. Sir Charles Lyell's standard of measurement is the date of the age of ice. If, therefore, the age of ice is assigned to a period 200,000 years ago instead of a million years ago, the standard of Sir Charles Lyell is diminished by four-fifths; and, adapting his conclusions to the altered premises, we should have forty-eight millions of years instead of two hundred and forty millions for the age of the fossiliferous rocks.

This change of standard would agree very well with the fact that there are evidences in the Eocene and Miocene periods of ice ages antecedent to the last. These might well be referred to the former periods of high eccentricity.

Enormous as are the periods which have undoubtedly passed since the creation of the world, it need not startle us to be told that every succession of events of which we have any evidence may well have occurred within a manageable number of millions of years. Could we stand, as Mr. Croll says, upon the edge of a gorge a mile and a half in depth, that had been cut out of the solid rock by a tiny stream scarcely visible at the bottom of this fearful abyss, and were we informed that the little streamlet was able in one year to wear off only one-tenth of an inch of its rocky bed, what would be our concep-

tion of the prodigious length of time that it must have taken to excavate the gorge? We should certainly feel startled when on making the necessary calculations we found that the stream had performed this enormous amount of work in something less than a million years.

The absolute settlement of the question must ever be above our powers. For a few centuries only we have the comparative daylight of historical times; thence backward lies the rapidly-gathering twilight of tradition; beyond that, geological periods the duration of which can be only vaguely guessed at, and beyond all these, far back in past eternity, the epoch when Time began. The old belief, which limited the existence of the earth to less than seven thousand years, gave way once for all, almost within living memory. All men are now agreed that the six days of creation were periods of indefinite extent. They are not solar days—for evening happened and morning happened three times over before the sun was created. Not being days measured by the sun, we know not how many thousands of years they may have endured. The reaction was sudden and complete. Geology jumped to the conclusion that the past history of the world was without any limits that human imagination could conceive. But in quite recent years, as we have tried to show, the calm light of science has proved that the practical eternity of matter is not more tenable than the arbitrary limitation by which thought was formerly confined.

"I dare say," says Prof. Tait, "that many of you are acquainted with the speculations of Lyell and others, especially of Darwin, who tell us that even for a comparatively brief portion of recent geological history three hundred millions of years will not suffice! We say—so much the worse for geology as at present understood by its chief authorities, for . . . . physical considerations render it impossible that more than ten or fifteen millions of years can be granted."

Sir William Thomson is not so sweeping in his assertion: but then the nature of the problem before him did not require any such opinion at his hands. His argument aimed at disproving Playfair's assertion that neither the heavenly bodies nor the earth offered any evidence of a beginning, or any advance toward an end. If, therefore, Sir William Thomson was able to show that there was good evidence both of a beginning and an end, he was not concerned to speculate how long past time had existed, or when the end would come. His summing up is this:

"We must admit *some* limit. . . . Dynamical theory of the sun's heat renders it almost impossible that the earth's surface has been illuminated by the sun many times ten million years. And when finally we consider underground temperature we find ourselves driven to the conclusion that the existing state of things on the earth, life on the earth, and all geological history showing continuity of life, must be limited within some such period of past time as one hundred million years."

We have passed in rapid review the evidence upon which guesses, more or less plausible, as to the age of the world, have been founded. Whatever may be the opinion at which men will ultimately arrive, it cannot but be satisfactory to note from how many quarters and in how many ways Natural Science has in latter days cast light on the inquirer's path.—*Quarterly Review.*

## THE LOCAL DISTRIBUTION OF PLANTS AND THE THEORY OF ADAPTATION.

By LESTER F. WARD, A. M.

THERE is one class of facts in the geographical distribution of plants which has not received, at the hands of botanists, the degree of attention which its importance justifies.

I do not refer to those wide general phenomena which a comparison of the floras of different countries renders so striking, and by which the more humble and restricted class to which I would call attention is usually eclipsed. Such general considerations are, it is true, exceedingly interesting and important, and are in no danger of receiving too much attention. Nothing could be more absorbing than a close comparative analysis of the vegetation of different hemispheres, continents, islands, and zones, of the globe. The most casual survey of such fields reveals marvels, the mere acquaintance with which excites in the mind of the botanist the liveliest interest and pleasure. The strange and leafless euphorbias of South Africa, with their naked, green, parenchymous branches; the equally singular and grotesque cactuses of America answering to them; the anomalous vegetation of Australia, with its shadeless forests due to their vertical foliage; the absence of oaks east of the Ural Mountains, and of heaths on this side the Atlantic; the confinement of the genus *Rosa* to the northern and of the genus *Calceolaria* to the southern hemisphere—these and numberless other kindred facts connected with the general distribution of plants over the globe are justly calculated to excite the most intense interest, and have given rise to a variety of theories designed to account for them.

The phenomena, however, to which I would more particularly refer, come much nearer home, and may be presumed to have attracted the attention, more or less forcibly, of every one at all conversant with plants. They constitute a distinct class, and may be described in general terms as facts unfavorable to the received theory of adaptation.

It has long been regarded as a law of life, applicable alike to animal and vegetable forms, that each species is exactly adapted to the particular habitat where it occurs; and naturalists, assuming this law,

have sought to solve the problem how this remarkable adaptation has been brought about, instead of pausing to question the alleged law of adaptation itself. And yet there have never been wanting numerous and obvious facts, especially in the vegetable kingdom, which, if interpreted at all, must be conceded to be incompatible with such a law, at least unless materially modified and greatly enlarged.

Mr. Thomas Meehan has remarked the fact that "almost all of our swamp-trees grow much better when they are transferred to drier places, provided the land is of fair quality." He referred, among others, to sweet-bay, red maple, weeping-willow, etc., as within his own repeated observations growing better out of swamps than in them." He further observes that "plants as a general rule, even those known as water-plants, prefer to grow out of water, except those that grow almost entirely beneath the surface." [1]

A great many facts are at hand to prove that those plants which are found habitually growing in wet ground may be easily made to grow in dry ground. The *Iris versicolor* (blue flag), which, in a state of Nature, grows universally in marshes, and keeps perpetual company with *Nuphar* (pond-lily) and *Sagittaria* (arrow-head), is a common occupant of the driest gardens. The *Lobelia cardinalis* (cardinal-flower), which I have found below tide-water mark, is also a common garden-flower, and not difficult to cultivate. Almost as much may be said for *Lobelia syphilitica* (great lobelia). The calla, the caladiums, and the anthuriums, belong to this class, and the list might be indefinitely extended.

But differences of moisture in the soil are not the only ones which are often overcome by natural or artificial changes in the conditions of growth. Most of our prettiest wild-flowers which are found growing in deep, shaded glens in pure leaf-mould, have been captured by florists, and made to thrive as well, and often better, under a cultivation which, with their most faithful efforts to imitate it, must be a complete alteration of their native condition of life. Of such might be mentioned at random the *Trillium* (wake-robin), the *Cypripedium* (lady's-slipper), the *Dicentra* (Dutchman's breeches), the *Uvularia* (bellwort), the *Erythronium* (dog's-tooth violet), etc.

So, too, plants growing under other conditions, as on hillsides, and in open woods or meadows, as the violets, hepaticas, anemones, and others, offer no difficulty to the florist.

These are cases in which the transfer is from apparently more favorable conditions to those less favorable. But similar results follow from a reversal of this order. Plants may be successfully transferred to ordinary garden-soil from localities which we would naturally suppose to be less favorable to growth, but to which these seem to be specially adapted. The columbine (*Aquilegia*), which grows on rocks, often with scarcely any soil in which to root, or emerges from narrow

[1] *See* POPULAR SCIENCE MONTHLY for May, 1874, p. 126.

crevices between them, is planted in gardens where it thrives equally well. The same is true of the *Cacti*, which, taken from the arid plains where their indurated watery stalks and branches store up the water which the climate so long denies them, thrive under cultivation with undiminished vitality. The *Agave*, or American aloe, furnishes a similar illustration, and every few years a gorgeous century-plant blooms under cultivation, to the infinite delight of its owner.

Equally striking results take place under the influence of man without his design or selection. There are a great many indigenous plants which are rarely found outside of the influence of human cultivation. They emerge from their obscure natural retreats at the approach of civilization, spread rapidly over fields and pastures, and often become formidable enemies of the farmer and the gardener. Under the general name of weeds they are proscribed and pursued, and no effort is spared for their extermination. They also invade towns and cities, overrun vacant lots, disfigure parks and plats, and force themselves into pavements and "crannied walls." *Ambrosia trifida* (the great rag-weed) forms forests in waste grounds and neglected gardens. *A. artemisiæfolia* (Roman wormwood) is one of the farmer's most persistent pests, and resists all efforts at extermination. The cocklebur and thorny clotbur (*Xanthium strumarium* and *X. spinosum*) warn us of their disagreeable presence wherever we go. *Polygonum aviculare* (knot-grass) and other species invade our door-yards and threaten to cross our thresholds. *Euphorbia maculata* (spotted spurge) spreads its prostrate and symmetrical mats over the dry and gravelly walks. *Spergularia rubra* (sand spurrey) unfolds its rosy petals to the hottest July sun upon the parching bricks beneath our feet. *Erigeron Canadense* (horse-weed), *Epilobium angustifolium* (great willow-herb), *Gnaphalium polycephalum* (common everlasting), and a host of other indigenous weeds, overrun the cultivated fields and commons wherever man has impressed his influence upon primitive Nature.

This phenomenon, however, becomes still more obtrusive when we turn to introduced species. And, if it be claimed that the transfer from waste places in the Old World to similar waste places in the New is not a change of conditions, we have only to remove our point of observation to Europe or Asia to render all that has been said of indigenous plants applicable also to adventive ones. For, unless we are willing to go further in admitting the transmutation of species than the founders of that doctrine, we must assume that each of these species has had a native habitat somewhere, and its preference for proximity to human habitations is unexplainable on any theory of original adaptation.

Illustrations on this point would be quite superfluous, as these plants constitute the bulk of all our weeds, and present themselves at every turn. I might mention the ubiquitous ox-eye daisy (*Leucanthe-*

*mum vulgare*), the iniquitous Canada thistle (*Cirsium arvense*), and the obnoxious burdock (*Lappa officinalis*), as examples of species which share with man, not only his cosmopolitan character, but also some of his vices. But these foreign immigrants often furnish us with one of the most striking exemplifications of the anomaly, if such it may still be called, which I am endeavoring to illustrate.

It frequently happens that a plant, taken from one country into another having an entirely different flora, thrives more vigorously than it did at home, and even threatens to drive out indigenous species. Some of the species last mentioned belong to this class, particularly the Canada thistle, which, notwithstanding its popular name, has been introduced into this country from Europe, and has spread not only over Canada and New England, but far south and west. *Cnicus lanceolatus* (common thistle) is only less prominent because less troublesome. The same is true of many plants of the mint family, particularly *Nepeta glechoma* (ground-ivy). On the other hand, some American species, like *Erigeron Canadense*, have migrated by the aid of man into almost every country on the globe, always thriving best where civilization is highest. But some of these do not confine themselves to the circle of man's protective influence. Sometimes they strike out into the forest or spread over the plains, carrying dismay to the native vegetation. Mr. Darwin, speaking of the introduction into South America of the cardoon (*Cynara cardunculus*), a congener of the artichoke, says: "It occurs in these latitudes on both sides of the Cordillera, across the continent. I saw it in unfrequented spots in Chili, Entre Rios, and the Banda Oriental. In the latter country alone, very many (probably several hundred) square miles are covered by one mass of these prickly plants, and are impenetrable by man or beast. Over the undulating plains, where these great beds occur, nothing else can now live. Before their introduction, however, the surface must have supported, as in other parts, a rank herbage. I doubt whether any case is on record of an invasion on so grand a scale of one plant over the aborigines."[1] He also mentions other analogous cases, though of a character less marked.

This love of change, if I may so characterize it, seems to inhere in the entire vegetable kingdom. Not even climate avails to overcome it, as is evidenced by the rapid invasion from the tropics of many plants whenever the presence of man in any manner creates the conditions favorable to their migration. Conspicuous among these are *Chenopodium* (pigweed), *Amarantus* (amaranth), *Ipomœa* (morning-glory), and others.

If we take a wider view of this class of phenomena, we may perceive that it is only by an extension of the same principle that all the beneficial changes made by man in the vegetable kingdom have become possible. Every plant he has improved and rendered subservi-

[1] "Naturalist's Voyage round the World," p. 119.

ent to his purposes has become what it is in obedience to an inherent tendency to exchange its original condition for a better one. And it is by taking advantage of this tendency and creating such better conditions that man has drawn it into his service.

This willingness and often eagerness in plants to change their habitat, sometimes without the least acclimation, enlarges, therefore, from the mere *lusus naturæ* which it at first appeared to be, into a law which is coextensive with plant-life. In view of the facts adduced, and others which will occur to the reader, we may conclude that the law of adaptation as popularly held requires extensive qualification if allowed to stand at all; that it is rather apparent than real; that large classes of facts are marshaled against it, and that some wider law is perpetually overruling it. The adaptations of Nature of which we hear so much are *not* perfect. Nature does not provide each species with a habitat best suited to its fullest development. But every plant is at all times ready to change its habitat for a better one, and this is actually going on whenever occasion permits.

Let us now inquire whether the facts enumerated admit of any general explanation. Mr. Meehan proposes to account for the better growth of swamp-trees in drier soil by maintaining that their seeds cannot germinate in dry ground. If this be true, it is a worse commentary on the theory of adaptation than I am willing myself to make without further proof. Certainly no intelligent adapting power could originate so gross and apparently gratuitous an inadaptation as an organism doomed to live out its existence under conditions unfavorable to its healthy development, because, forsooth, it could *begin* its career only under such conditions! But, as both the theory and the commentary rest on a teleological basis, they are both worthless from a scientific point of view.

But, however this may apply to the trees enumerated by him, it certainly does not apply to many plants of the same class which I have named, for florists propagate them from the seed when they choose. Still less can this explanation be admitted to account for any of the other classes from which illustrations have been drawn. And, indeed, I am not aware that any attempt has ever been made to bring forward a rational explanation of a general character for the facts under consideration. Botanists, generally, seem to have been either too much dazed by the light of those more universal and striking features to which attention was called at the outset, or too intent on the special study of the facts themselves, independent of the lessons they inculcate, to have worked out a solution for the problem I have been seeking to present. But the chief obstacle, after all, to such a solution, is to be found in the satisfaction which every one seems to feel with the old explanation, viz., that plants grow in particular places because they are adapted to them and to no other, which, as we have seen, is opposed by a strong array of facts.

In this theory of perfect natural adaptation, whether it be left to stand upon its old teleological basis, or be placed, as some modern investigators would place it, upon a genetic one, a very important factor has been left out, viz., the influence which plants exert upon one another. Adaptation, as the term is employed, is applied to a supposed correlation between the plant and its *inorganic* environment; and to this alone is attributed their entire local distribution. But facts of the class above considered prove that this is not only an inadequate explanation of such distribution, but that it is in many cases no explanation at all, since they so generally disregard inorganic conditions, and thrive equally well or better under entirely different ones from those which Nature furnished. Their distribution must, therefore, be almost entirely attributed to some other conditions; and to what other conditions are they subjected but to organic ones, to those which they reciprocally impose upon each other? It is to these organic conditions, then, to the mutual influence of different kinds of vegetation, growing, as it always does in a state of Nature, in close local proximity and contact, that we must look for the chief laws that control the local distribution of plants.

The modification, therefore, of the adaptation theory, or rather the substitute for it, which, in the light of these facts, I would propose might be called the law of *mutual repulsion*, by which every individual, to the extent of its influence, repels the approach of every other and seeks the sole possession and enjoyment of the inorganic conditions surrounding it—this mutual repulsion results at length in a *statical* condition which is always brought about through the action of the vital forces themselves, and which, as soon as reached, determines absolutely the exact place and degree of development of each species and each individual.

It is this statical condition which is apt to be lost sight of in the modern philosophy of evolution. The modification of species, the survival and advancement of some and the depauperating and extinction of others, all forms of variation and transmutation—these are *dynamical* phenomena, and only take place under the influence of disturbing agencies. Changes of this kind are slow and secular, and lie beyond the reach of direct observation, perceptible only to the eye of reason on the closest comparison of large masses of dependent facts. They, therefore, long escaped observation, and Nature remained until recent times a sealed book with respect to them. What wonder, then, that this still deeper and more occult law of biological statics should have remained still longer undetected, or only dimly seen? For, underlying this dynamical movement in organized beings, there must exist a universal statical condition throughout organic as throughout inorganic Nature.

The changes of which science has at length caught a glimpse can be nothing more than the regular and cyclical or fitful and spasmodic

disturbances of a deeper and universal state of forced equilibrium, which pervades the vital as it is known to pervade the mechanical world. And just as astronomers and physicists, confining their investigations to the more obvious and perceptible motions of celestial and terrestrial bodies, long remained ignorant of the law of gravitation which constantly forces all things into a state of equilibrium, so in biology the statical condition has been lost sight of in the effort to obtain better views of that moving panorama which a broader knowledge of the phenomena of life so unmistakably unfolds. Yet, without a clear recognition of this statical law, it is impossible to account for the facts presented by the distribution of plants, and it will doubtless be found equally essential to the full comprehension of many other phenomena of Nature. But, when we recognize this law, the whole aspect of our question is changed. Plants appear to be no longer in a state of perfect adaptation to their surroundings.

There is no longer a necessary correspondence and correlation between organism and habitat, no longer necessary that rhythmical (almost preëstablished) harmony between species and environment. This need only exist so far as is necessary to render the life of the species possible. Beyond this the greatest inharmony and inadaptation may be conceived to reign in Nature. Each plant may be regarded as a reservoir of vital force, as containing within it a potential energy far beyond and wholly out of consonance with the contracted conditions imposed upon it by its environment, and by which it is compelled to possess the comparatively imperfect organization with which we find it endowed. Each individual is where it is, and what it is, by reason of the combined forces which hedge it in and determine its very form. Each species is the perpetual and inexorable antagonist of every other. The "struggle" is not alone "for existence," it is also for *place*. In the plant races, as in the human, there is a recognized hierarchy, the laws of which are as yet to a great extent involved in mystery. But the first principle, as in the rest of Nature, is force. Each one encroaches with all the power of vegetal growth upon its neighbors. This pressure is enormous. Who shall calculate this subtilest of molecular forces? Yet there is no displacement, no motion. So thoroughly has every nook and chink been filled that there is no room for motion. Like the all-pervading circumambient air, its power is not felt so long as no vacuum is produced. Each organism has long since reached the limit of its power to extend its dominion. The plant grows up from the germ to maturity under a constant surveillance, and every attempt to overstep its fixed limits is instantly checked. It stands in its fixed position, locked in the embrace of forces which permit it neither to advance nor retreat.

Such is the state of equilibrium which is always and necessarily reached in a state of Nature, and in which man first finds each newly-discovered flora. But let these statical conditions be once changed,

whether by the advent of man or from whatever cause, and this equilibrium is immediately disturbed. The chained forces are set free; a general swarming begins; some individuals are destroyed, others are liberated; each pushes its advantage to the utmost, and all move forward in the direction of least resistance, till at length they again mutually neutralize each other, and again come, under new conditions and modified forms, into the former state of quiescence.

The most frequent and prominent cause of these disturbances of the natural fixity of vegetation is the influence of man. The results of this influence may be said to be the products of agriculture, horticulture, and floriculture, on the one hand, and, on the other, weeds. But there may be many other causes of disturbance besides that produced by man, such as the appearance of new animals, geological revolutions, or climatal and meteorological vicissitudes. Anything which destroys the stability which the perpetually-operating vegetal forces impose upon the plants of any region is certain to reveal a latent vitality, which, when liberated, proves itself capable of profiting by conditions far different from, and superior to, those under which it is originally found. The willow, the alder, the elm, and the sycamore, hug the banks of streams because baffled and beaten back at every attempt to invade the drier ground. The wild-columbine and the saxifrage are driven into their rocky fastnesses by more powerful rivals for the rich forest loams. The thistle and the chamomile flourish in lawns and commons because their human foes are less formidable than the enemies of the plain. The fruit-trees, the cereals, and the roses, reach those wonderful heights of development under man's care, because he not only proves their friend, but wards off all their enemies. And just here it should be remarked that the alleged tendency of cultivated plants to relapse, when neglected, into their original state, upon which Prof. Agassiz laid so much stress as an unanswerable argument against transmutation, becomes, under the law of mutual repulsion, the necessary result of remanding them to their old conditions. As man's care and protection were necessary to enable them to advance, so, when these are withdrawn, they must be expected to again yield to hostile forces, and fall back to the level of their original state. It is not the special adaptation of a plant for the spot on which it grows, so much as the hostile attitude of other plants around it, which restricts and determines its range. The elements which decide where plants shall grow, are to be found in vegetation itself, and not in inorganic conditions. The power of self-adaptation which they possess is sufficient to habituate almost any species to almost any inorganic conditions. Each species, therefore, keeps within its own restricted limits, not because it cannot live in other soils, but because prior occupants forbid it to come.

The law of adaptation may therefore be reduced to this: that every plant possesses the power of self-adaptation to such a degree

that, no matter under what conditions it may be compelled, by the higher law of mutual repulsion, to live, it will mould its own organism into harmony with those conditions, and thus continue its existence; and this, whether it is required to adopt a more perfect or a less perfect form.

But what it actually is, is no criterion of what it is capable of becoming, and the locality in which it is found is no evidence that it is best adapted to such a locality. These data only prove that in the final balance of forces to which it is subjected it was assigned such a degree of development and such a habitat.

## OBSERVING THE INTERIOR OF THE EYE.[1]

By JULIUS BERNSTEIN,
PROFESSOR OF PHYSIOLOGY IN THE UNIVERSITY OF HALLE.

THE retina is the point where the physical process of vision passes into the physiological process. Until it impinges upon the retina, the light which penetrates the eye has only undergone physical changes, consisting chiefly in refraction, the last perceptible result of which is the production of the image upon the retina. From this point the process passes from our immediate observation, and the difficulty of discovering its character increases at each step. The image upon the retina is reversed, and yet we see every object in the field of vision upright. This is the result of the experience, which we have acquired from childhood, in the exercise of the organ of sight. The point *A* (Fig. 1), which is on the right, is imprinted upon the left portion of the retina, and we, therefore, know by experience that a

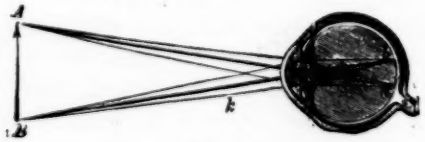


FIG. 1.

ray, coming from the right, must strike the left portion of the retina; and because we always imagine the objects we see to be external to ourselves, we must do so by unconsciously following the line *a A*, through the optical centre *k*. In this manner the eye projects a uniform field of vision, which is obtained by drawing, from every point of the retina outward, straight lines through the optical centre of the eye, which lines will terminate upon a convex surface.

This is really the manner in which the eye interprets, in all cases,

[1] From "The Five Senses of Man," No. XXI. of the "International Scientific Series."

its sensations of sight. For luminous appearances may be produced without our perceiving any external object, but merely a part of the eye or an inward irritation; and yet, in the same manner, we imagine them to be external to ourselves.

If we shut the eye, and press the head of a pin upon the outer edge of the eyeball, we shall see in the dark field of vision a white or colored spot of light, which has the same form as the compressing body. It will be seen upon the left side of the field if the right side is pressed, and upon the upper half if the lower is pressed, and *vice versa*. The retina, therefore, extends as far as the part which projects beyond the socket of the eye, and can be irritated by pressure. It is well known that when the eye is struck a cloud of sparks is seen, which is caused by the mechanical concussion of the retina. These luminous images, often perceived involuntarily, take, speaking scientifically, the form of the body producing the pressure; at the same time we observe the relation between the position of the irritation and the position of the sensation of sight. We transpose a point on the left side of the retina to the right, because we imagine that a ray of light has penetrated the eye from the right, which must fall upon the left half of the retina.

We are also able to perceive particles within the interior of the eye which are found in the transparent media. There are many persons who always see round particles or filaments, which seem to float about in the field of vision. They may be more distinctly seen when looking upon a bright surface—a cloudy sky, or through a microscope. They follow every motion of the eye, and have, moreover, a peculiar motion of their own. These particles are produced by filaments and cells, which may be found floating about in the narrow space between the hyaloid membrane and the retina. They cast their shadow directly upon the retina, which then, from experience, refers them to external objects.

It has also been discovered by more careful observation that the refracting media of the eye are not absolutely transparent, but that a kind of cloudiness is seen in places which throws a shadow upon the retina. If we look at the sky through a small hole in a sheet of paper, held a short distance from the eye, the hole will appear to be surrounded by a colored fringe. This is caused partly by a cloudiness in the vitreous humor, and partly by the peculiar radiating formation of the lens, already described. All such phenomena are called *entoptic*, because they deal with the perceptions of the internal portions of the eye. They are produced by the incident rays of light casting shadows of these particles upon the retina. They are best seen when an isolated pencil of light, like that admitted through a small aperture, is allowed to fall upon the eye; for, in that case, the shadows produced are distinct, while they are generally obliterated in ordinary vision, because the light penetrates the eye from all sides.

One of the most interesting entoptic phenomena is the *Arborescent Figure*, discovered by Purkinje. If, toward evening, we place ourselves opposite a dark wall in a dark room, and move a lighted candle to and fro before our eyes, looking, however, fixedly at the wall beyond, we shall then, after a little practice, see this arborescent figure, whose intersecting branches cover the whole of the dark space, and which is unmistakably caused by the blood-vessels in the interior of the eye. The field of vision assumes a reddish appearance, upon which the veins stand out in dark shadows. The trunk of the figure rises a little on one side of the centre, where the optic nerve enters the eye, and thence branches out after the manner of blood-vessels, which is undoubtedly a proof that in this experiment we see the blood-vessels of the retina itself. One spot alone is free from vessels: the yellow spot, which is the most sensitive to light of all parts of the retina. If, now, the candle is moved to and fro, the figure will also move and follow the direction of the light.

All these observations lead to the conclusion that we are thus enabled to perceive the shadows of the vessels of the retina. That these vessels cast a shadow behind them is clear, but that the shadow should be sufficient to cause a perception leads to the very important and interesting fact that the elements of the retina which receive the impression of light must lie behind the blood-vessels. The diagram in Fig. 2 will explain how the shadow of a vessel can produce an image. If the light is placed at *a* its image will be depicted upon

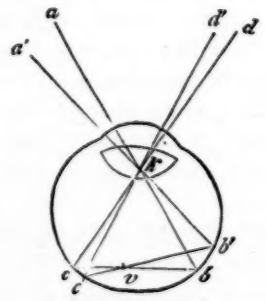


Fig. 2.

the retina at *b*. At this particular spot no vessels will be seen, because the light is too dazzling. But the image at *b* forms another source of light, and, if there is a vessel at *v*, then its shadow will be thrown upon *c*. Now, the retina projects the image perceived at *c*, outward, through the optical centre *k*, to *d*, where the vessel appears in the field of vision. If the light is now moved from *a* to *a'*, then the image will move from *b* to *b'*, the shadow from *c* to *c'*, and the image of the vessel from *d* to *d'*, thus performing the same movement as the light. We do not, however, generally perceive these retinal vessels, because usually the light falls upon the retina from all

points of the pupil, and therefore no distinct shadow can be produced. In the experiment just described the light proceeds from a single point only, *b*, and produces a distinct shadow. Moreover, the light is an unusual one, and throws the shadows upon places which are not accustomed to receive it. This latter circumstance seems to be of some importance, for, if the light is held perfectly still, the figure gradually fades away, because the sensitiveness of the parts of the retina upon which the shadow is becomes blunted; it appears again, however, if the light is moved from side to side, so that the position of the shadow is changed.

A considerable amount of light penetrates the eye through the pupil, which is quite sufficient for the representation of the external world, but none of this light seems to be reflected. The pupil of the eye generally has a dark appearance, so that we cannot see farther into the eye than the iris. It is, however, possible to illuminate the eye in such a manner that all the parts of the retina may be seen. This was first done in a satisfactory manner by the celebrated physicist Helmholtz, the discoverer of the ophthalmoscope. Before describing this apparatus and its functions, we must discuss the fact of the dark appearance generally presented by the pupil.

The amount of light reflected by the background of the pupil cannot, of course, be very great; for the retina alone is able to reflect light, and as it is very transparent, and has, moreover, a dark layer of pigment immediately behind it, which absorbs all the light that has penetrated to it, the reflection must necessarily be weak. We know how difficult it is to see through a window into a room from the street. This is due to the small amount of light which comes through the window, in comparison to that which penetrates the eye from without, so that the eye is not sufficiently sensitive to perceive the weaker impression; moreover, the reflection from the panes of glass considerably increases the difficulty of perceiving objects in the interior of the room. If, however, the room is lighted up at night, we can see the interior very distinctly from the outside, although the illumination of the interior is weaker than it was in the daytime.

These circumstances also apply to the eye; but there is another circumstance which adds to the difficulty of examining the interior of the eye. The same fact makes it impossible to see the background of a camera-obscura through the lens, even when it is white. According to the laws of refraction, both the incident and emergent rays in the eye, or in a camera-obscura, have a fixed direction, while the light which proceeds from a room through the window is diffused—that is to say, emits rays in all directions. Let us suppose an image of a lighted candle to be thrown upon the retina; then, as far as the refracting media of the eye are concerned, this image may be regarded as a second object, the rays from which will take an outward, and therefore opposite direction. Now, this will be precisely

the same as the path of the incident rays; for if, at the point where an image of an object has been formed by a lens, we place an exactly similar object instead of the image, then an image will be formed in the exact position of the first object, and of equal size. We see from this experiment, therefore, that the rays of light, which are emitted by an image formed upon the retina, must return to the object from which they originally proceeded.

If, therefore, a light is placed before any eye which we wish to examine, the rays will all be reflected by the eye into the light, and we are unable to intercept them by our own eye, because we should hide the light by placing ourselves between it and the eye under examination. By means, however, of a transparent plate of glass, this obstacle may be overcome, and the eye examined when illumined, in the manner represented in Fig. 3. *C* is the eye under observation, *B*

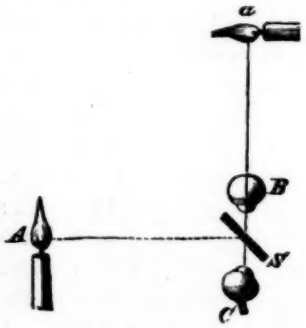


FIG. 3.

the observer's eye, and the plate of glass, *S*, forms an angle of 45° with the line between the two eyes. The rays emitted by the lighted candle, *A*, strike the glass plate, *S*, and are partly reflected into the eye, which they illuminate. The rays reflected by the eye, *C*, again strike the glass plate, which some of them penetrate, and pass into the eye of the observer, and the remainder return to the light, *A*. The pupil of the eye, *C*, may now be seen brightly illuminated, and even the illuminated retina can be seen more or less distinctly. The rays emitted by the image formed upon the retina, which pass through the glass plate, would form an image at *a*, which is at the same distance from the glass plate as *A*. The rays are, however, intercepted by the observer, *B*, who is thus enabled to examine a part of the retina.

In fact, a piece of window-glass placed in an oblique position, as described above, is the simplest form of an ophthalmoscope, and may easily be arranged by any one who wishes to make the experiment for himself. An ordinary piece of glass is sufficient for the purpose, if placed in the same position, relatively to the eye under observation and the light, as that shown in the figure. It is well to place a

screen between the light and the person under observation, to prevent any annoyance arising from the intensity of the light. The observer must then place himself close in front of the person whose eye is under observation, hold the glass in the manner described, and move it about till the reflection of the light falls upon the eye. The illuminated pupil will then be seen through the glass, and appear of a reddish color.

But, in order to see the separate parts of the retina distinctly, it is necessary to make use of lenses adjusted to the sight of the observer, and the refractive power of the eye under observation; and the result of such a combination is a perfect ophthalmoscope. The glass, again, has been replaced with advantage by a mirror, generally a concave mirror, with an aperture in the centre, through which the observer looks. Fig. 4 shows the method of using this apparatus, constructed after Ruete's plan. The light is placed near the person under observation, *A*. The rays emitted fall upon the concave mirror, *d*, which reflects them into the eye under observation. The ob-

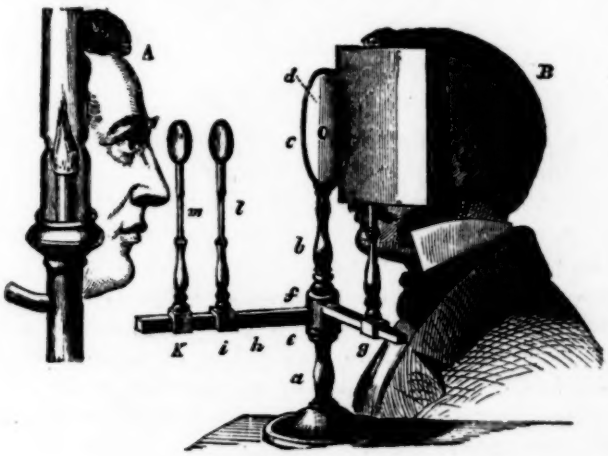


FIG. 4.

server, *B*, looks through the aperture in the concave mirror, and moves the two lenses, *m* and *l*, till they are in such a position that a distinct image of the retina appears.

We are now in a position, with the aid of the ophthalmoscope, to make a thorough examination of the retina. Fig. 5 gives a tolerable representation of all that we are able to distinguish of the image. The background of the whole is of a dull red, while the point where the optic nerve enters is distinguished as a round, bright spot, and we may see rising out of its midst the retinal vessels, arteries, *a*, and veins, *b*, which extend over the entire retina. The yellow spot also, the point of most distinct vision, may be distinguished as a small bright spot.

The ophthalmoscope has become an instrument of incalculable value to the oculist. Many changes in the retina and interior of the eye, which are due to disease, can be observed and examined by means of the ophthalmoscope; and, in fact, the medical treatment of the eye has made an immense advance since the discovery of this instrument.

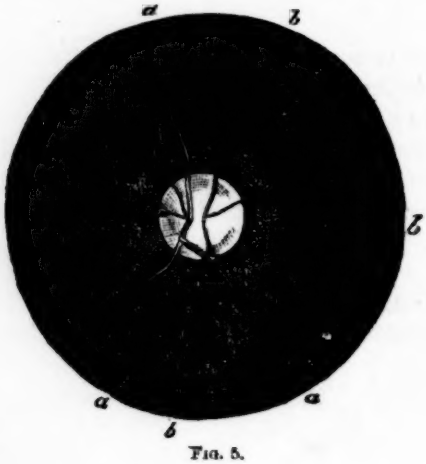


FIG. 5.

The eyes of many animals—those of cats, for instance—exhibit a peculiar brilliancy, which is particularly remarkable in the dusk. It was formerly thought that the eyes of such animals emitted light independently, as it was also thought that light could be emitted by the human eye, under the influence of passion. This brilliancy, however, in the eyes of these animals is caused by a carpet of glittering fibres, called the *tapetum*, which lies behind the retina, and is a powerful reflector. In perfect darkness no light is observed in their eyes, a fact which has been established by very careful experiments; but, nevertheless, a very small amount of light is sufficient to produce the luminous appearance in them.

## SCIENCE AND RELIGION AS ALLIES.

BY JAMES THOMPSON BIXBY.

THE antagonism between Science and Religion has become a commonplace of literature. Both preachers and physicists have narrated with bitterness of spirit the battles which they have fought, the wrongs which they have suffered, the complaints which they have to make, the one against the other. The combative have plunged into the *mêlée*, and with slashing pen or tongue given it new asperity and new sources of grievance. The peaceful have endeav-

ored by various reconciling schemes to persuade the combatants to lay down their arms. Historical spirits have searched out and retold the forgotten incidents of the struggle; the philosophic-minded have explored its secret springs. In one way or another all have drawn the attention of the world to the hostile attitude of the two.

Now, it is true that there have been no small number of conflicts between science and religion. But is the whole account of the relation of the two contained in this? Is there not another part to the story? I believe that there is.

Much, it seems to me, might be said in exhibition of the *mutual indebtedness* of science and religion, as well as of their hostilities. Having heard so much of late about the latter, perhaps it may not be unprofitable to consider a little the other side of the shield.

In the first place, religion is much indebted to science. Science has not been a mere iconoclast of everything sacred, but it has been a real helper in the progress of religion.

In the marvelous adventures through which Rabelais conducted his hero Pantagruel, a clime was reached so cold that the words of the men, it is said, as they passed the lips, froze and fell as hail on the deck; but, brought near the fire, the congealed words thawed and gave up their sounds. So, under the sunbeams of science, the dumb matter, the frozen thought of the Creator, melted into intelligible accents and spoke forth its secrets. Sun and cell, magnet and crystal, have each found a tongue and told the world of facts, exhibited to it achievements that, if predicted a thousand years ago, would have seemed like nothing but a chapter out of the Arabian Nights Entertainments.

Now, these triumphs of science have not redounded merely to the empty glory of their hero, but they have been solid contributions also to the benefit of man and to the glory of God.

What other argument for the existence of God has done more for theism than the argument from design? In the admirable harmonies and adaptations of the world, the natural theologian finds the most convincing illustrations of a Supreme Intelligence anterior to the universe. Whence is it that a knowledge of these instances of contrivance and order has been obtained? Plainly, it is from the scientific study of Nature that the overpowering strength of this argument has been derived. Ordinary observation—to be sure—would, of course, first suggest the argument and present not a few illustrations. Three thouand years ago the Psalmist put those forceful questions—"He that planted the ear, shall he not hear? He that formed the eye, shall he not see? He that teacheth man knowledge, shall not he know?"

Here lies, indeed, the gist of the whole argument from design. Yet it is to modern physical investigations, in anatomy, chemistry, natural history, that we owe those exquisite illustrations of curious

adjustment and interdependence that in the hands of a Paley or a Sir Charles Bell have given the design argument such force and sweep. Compare the proofs of God's unity and intelligence open to a David or a Paul with those which Prof. Cooke finds in chemistry, or Winchell in geology, or Agassiz in natural history, and how much more manifold and marvelous the latter!

In the next place, science has been most helpful to religion in purifying its faiths and guiding its reverences. Now, this is a service that Faith much needs to have some one to do for her. For, sublime as are her aspirations, her intellectul vision is but dim. Her eye fixed on the heavens to which she would climb, she cannot discern distinctly the steps by which it is reached. She needs science ever to be at hand to direct her. In her mounting instinct, Faith stretches up her hand and clutches and clings to whatever she comes across. The misshapen tree which rescued the savage from the wild beast; the black stone which fell from the sky; the serpent or the crocodile whose strange form and power fascinate the primitive man—such are the objects that humanity, in its first dim gropings for an object of worship, embraces. Religion may remain long in this groveling stage, as it did among the Egyptians and Assyrians. But sooner or later, as knowledge increases, the powerlessness and the worthlessness of such things for the worship of thinking men are seen. Faith reaches up her hand to higher objects—the invisible but potent wind, the outstretched sky, the ethereal fire, the sun that warms and lights the whole earth. These are looked upon as mighty living beings, and venerated in solemn rites. But, again, as man learned more of these—the fixed laws which they obey—the confined paths in which they move, and, in learning this, learned more of himself—he recognized in conscious Intelligence and the overruling Will something greater than wind or fire. Faith raised her reverence, then, to a divinized humanity, a company of human gods—Jove, king of heaven, and Juno, queen; Mercury, messenger of the gods; Cupid, inspirer of love; and so on. But, again, with the growing comprehension of the unity of all Nature, man rose to the idea of a single supreme deity, a Jehovah—the eternal I am—Brahma, the one reality, of which all else are masks and shadows—and thrust down the other deities into the position of divinities, spirits, and devils. Still Religon had not got above superstition. She still clung for a long time to burnt-offerings, and washings, and fastings, macerations, and masses; interferences by good and evil spirits; ideas of God as jealous, wrathful, appeasable, repenting of what he had once done, interposing to mend his work. Gradually-increasing knowledge pulled one after another of these rounds also out of the hands of Religion, and her yearning fingers that must clasp something reached up still higher on the ladder of divine apprehension, until at last she grasped the conception of the universal, eternal action of One Infinite

Perfect Being, without parts, without partiality, and without shadow of turning, to be worshiped only in spirit and in truth.

Science, to be sure, in this process of purification, has destroyed a great deal that has been very dear to Faith. It has uprooted old ideas and pulled down about our ears accepted systems—both physical and spiritual systems. The change in our views of the world has been most radical.

What was the conception of the world held by the orthodox churchman of the middle ages? The earth was a square plain, at whose outer edges rose mountain-walls, supporting the vault of heaven. This vault was a solid crystal roof, wherein the fixed stars were set, and over which moon and sun were pulled to and fro by the angels. Above this firmament, separating the waters which are above from the waters which are below, was the celestial cistern through whose windows the rain fell. Above this, again, the seven-storied heaven, in whose highest story dwelt Jehovah himself, seated on his throne of glory, surrounded by angels and saints.

To-day, how has science stretched out this little cosmos! The astronomer has turned his telescope upon that adamantine firmament, and it has dissolved into thin air. The total solid particles that the blue expanse contains, it has been estimated by Tyndall, might probably be packed into a lady's traveling-bag. The glittering points that gemmed its surface have expanded into enormous sums—thousands of times as large as our own globe. The circumscribed heaven of the Apocalypse, 12,000 furlongs each way, has spread out, from that one-hundredth part of the cubic dimensions which we now know our own earth to have, into an immensity of space which puts us so far from the nearest fixed star that a locomotive could not reach it in 700,000 centuries; and that even when we had attained this enormous distance we should stand merely at the entrance of a starlight avenue, down whose infinite vista come the rays from still more remote suns! Our own earth, formerly the grand, immovable stage to which the wandering sun and stars were only decorations, has been shriveled into a petty pellet of cosmic stuff, dislodged from its fixed and central position, and sent whirling on its way as one of the smaller satellites in the train of a central body, which central body, though as much larger than it as a cart-wheel is than a pea, is yet but one of more than 20,000,000 suns contained in its own part of space; and is itself not stationary, but moving with its planetary fleet at the rate of 4,000 miles a day round some still larger centre.

And in time, as well as space, has science enormously multiplied the numbers. Where the Bible chronology gave sixty centuries for the world's age, science demands as many millenniums. Where Genesis granted six days for the business of creation, geology requires as many æons. Science has mined in caverns and found man's tools and weapons among the bones of mammoths. It has deciphered

hieroglyphics and found arts and history already venerable before the date when commentators admitted that Adam was created. It has learned how vast beds of chalk and limestone, miles in thickness, have been manufactured by microscopic creatures; how from a fiery cloud the globe gathered to a molten ball, and on the molten ball formed the crust that now suspends us above the still furnace-heated interior. Learning little by little all this, science has been compelled to put the date of the cosmic beginning back into an antiquity that, in comparison with the Mosaic work, seems an eternity.

And in thus prolonging the age of man and the world, science has altered our conception of the method by which the universe came into existence. It can no longer be looked upon as created out of nothing, at one grand *tour de force;* but as a process of organization, a process continuous and alike in every atom. In the glowing, gaseous nebula, in the curdled, nucleated fire-mist of the embryonic star, in the more consolidated, but still molten, heaving mass of our sun, in the ring-girt Saturn, the still steam-enveloped Jupiter, the sunny summer-time of our own planet, are discerned by the modern physicist the various stages through which every planetary system passes. From the heterogeneous to the homogeneous, from the diffused to the compacted, from the unorganized to the organized, from the lifeless to the living, this is the eternal rhythm of the cosmic evolution.

The cosmic evolution! Yes, this is the further and mightier change which science has made in our conceptions of the world's government. In the current belief of Christendom even 200 years ago, this earth was a world of decay and supernatural intervention, ever to be dreaded. Powers of darkness were struggling with the powers of light in ceaseless efforts for the mastery. Close underneath the earth's surface were the fiery pit and the gloomy realms of purgatory. Through caverns and secret ways mischievous devil and perturbed spirit passed up and down. The graveyards were haunted by ghosts. A comet foreboded disaster to nations, and an earthquake was the overture to the judgment-day.

By a compact with Satan a sorcerer could blight the harvest, or lay low whomsoever he wished with fatal disease. Ordinary phenomena, of course, were supposed to take place as the result of the natural arrangements instituted at the creation, but whatever was at all out of the usual order was looked upon as a special intervention, either of saint or magician, imp or angel, Satan or God, according to its respective evil or goodness, littleness or greatness.

All this science has ejected from the belief of enlightened men. Instead of a fall of the human race, and increasing ruin in the world, science has shown the gradual upclimbing of the race from cave-dwellings and garments of skin to the luxuries and enlightenments of our present civilization. Men of science have been over the whole earth and scrutinized the whole heavens, exploring every dark corner

and strange event. Their best instruments have caught sight of no devil, their deepest mining-shaft has reached no limbo of departed souls. They have traced beforehand the path that the comet would pursue, found the cause of the earthquake, the connection of disease with its physical antecedents and antidotes. Spectres have been reduced to illusions of the visual organs, and lunacy to affections of the cerebral lobes. The witches and imps of the old dispensation have vanished before the light of modern knowledge like shadows of a hideous night. Interruptions of the established order, whether by wizard or holy exorcist; special dispensations and interventions, whether from the realm of *diablerie* or providence, are no longer credited; but law, inflexible law, without the slightest slip or variation, is believed to reign always and everywhere. Lily and solar system unfold according to one and the same formula. The hallucination of the senses, the insane delirium, these also have their natural sources from which they flow in a regular order. Even in the exception lies hidden some deeper law.

With such a strong and iconoclastic hand has Science plied the axe in the domain of Faith. As every one knows, it has been exceedingly painful to many pious souls. It is charged that these reconstructions which modern inquiry have made and are making unsettle all the foundations of religion; that they strip off the bloom of mystery and sacredness from the flowers of faith and conduct to irreverence. Are they, in truth, to be deplored? It seems to me that they are not, but to be rejoiced at. It is true that they have given the death-blow to many forms of faith. It is true that they have disabused us of many ancient venerations. To-day, when we carry flame sealed in our vest-pocket ready to come forth at the scratch of a match, no fire-deity, of course, receives any longer the sacrifice of our first-born. To-day, when we bottle up the lightning and make it our errand-boy, we no longer revere it as the bolt of Jove. But for everything that Science has taken away from Religion, she has given her something greater. If she has weaned her of her blind awe of the unknown, she has substituted a more rational awe of the known. If with ruthless hand she battles down every baseless tradition and fond illusion, she consecrates with religious veneration the simplest real fact. If Nature no longer is the object of human dread, yet, as the useful storehouse whence we draw food and treasure, as the friendly Titan who performs for us tasks beyond our unassisted power, it holds a higher place. If the astronomer's lens has dissipated the ancient heavens, it is to show us system behind system of celestial bodies, blazing at immeasurable intervals in the depths of illimitable space. If geology has taken away the idea of a creation finished once for all in a certain six days of the year B. C. 4004, it has given us instead a continual process of moulding and perfecting carried on for 100,000,000 years. The rigorous probing that science has given to Nature does not remove any of its won-

derfulness, any of its perfection, but rather has disclosed new marvels behind those which first struck man's attention. The widening of the circle of the unknown has only served to confront us with deeper and deeper mysteries. Science has ruled out miracle and magic from the order of events, but it is to pick up the wizard's wand itself, bring up before us daily stranger and grander phenomena, only the more inexplicable and amazing because of the certainty we feel that somehow there is no exception in them to our most ordinary experience.

Science has expelled witch and elf, nymph and demon, and thus depopulated the supernatural world; but in the place of this uncanny brood, the thought of whose capricious intervention paralyzed the will and debauched the heart, the universe has been filled with the presence of *One*, Eternal and Infinite, from whose perfect law we can never escape. The more clearly we discern the path on which science has led the world, the less fear shall we have that it is all a preparation for precipitating us into some godless abyss. Put the case squarely before any one in its full significance, and there is no one, I think, who would prefer to go back to the cosmic baby-house of the middle ages. Who would vault in again the immensity of space? Who would cut down to six ordinary evenings and mornings the activity of Him who inhabiteth eternity? Who would relinquish the confidence and hope inspired by the unswerving progress of that single divine purpose that links the ages together?

Thus has science given to the cause of faith assistance which more than countervails whatever injury it may have done.

And so has Religion also, in reality, helped science—helped, I believe, even more than she has hindered.

It is to the understanding that the great achievements of physical inquiry are commonly referred. Science is spoken of as a domain of dry light and clear-cut facts, and religion is contrasted with it as the realm of emotion. But how could the intellect have ever gained its great victories without the aid of the heart? how could the senses have ever penetrated into Nature as they have done, had they not been carried on the wings of the spirit? What could science accomplish without the emotions of enthusiasm and devotion, the instructive feeling of truth and beauty, the love of Nature for its own dear sake? "It is in vain, I think," said Prof. Tyndall, at London, in 1869, "to separate moral and emotional nature from intellectual nature. Let a man but observe himself, and he will, if I mistake not, find that, in nine cases out of ten, moral or immoral considerations, as the case may be, are the motive force which push his intellect into action." The reading of the works of three men, he proceeds to say—Carlyle, Emerson, and Fichte—neither of them friendly to the scientific spirit, carried him victoriously through mathematical studies and physical investigations, and made him the man of science that he is. To the same effect is the striking declaration of that other great leader of scien-

tific thought of to-day. "The great deeds of philosophers," says Prof. Huxley, "are less the fruit of their intellect than of the direction of that intellect by an eminently religious state of mind."

Consider the characteristics demanded in the successful study of Nature, and we shall discern the spiritual source whence these physical triumphs come.

One of the first requisites in the inductive method is the humble-mindedness that will completely submit itself to the evidence of the facts. "Access to the kingdom of man, which is founded on the sciences," Bacon aptly says, "resembles that to the kingdom of heaven, where no admission is conceded except to children."

Another condition of success is the spirit of industry that is unswerved by love of ease or idea of labor's dishonor. Another, again, is the candor that will look on all sides of a case, and listen to every objection—consecration to truth as the primary object. These are the qualities which men of science set forth as the requisites for walking within the veil of the temple of Nature.

But what else are these than the very graces of Christianity? Take the childlike mind that the founder of the inductive method demands: it is just what Christ enjoins. Take the fearless love of truth that seeks the absolute facts—the cause behind the cause. How long would it hold on its way did not spiritual aspiration ever feed its secret springs with the insatiable hunger after perfection? Take that diligence in labor and honorable estimation of work which is one of the essential instruments of scientific work, and ask what is the impulse that has endowed modern Christendom with it. "Labor," as a German writer of weight has well pointed out, "was considered by our heathen forefathers a dishonor; and even in the present day, where the gospel is not preached, the stirring disposition, the assiduity, the spirit of enterprise in the people, is disproportionately less. The duty and dignity of work is one of the priceless gifts to modern science of him who said, 'My Father is working up to this time, and I work.'"

Or consider that interest in Nature that is such a powerful spring of physical inquiry. Consider that sacred claim of his vocation which the true servant recognizes—such a sense of it as leads a Lyonnet to spend his life counting the 40,000 muscles in a caterpillar's body! Is it not the Christian spirit, the belief, that is, in the brotherhood of man and the duty of self-sacrifice—the feeling of filial loyalty to a Divine Father, all of whose works are significant, and all of whose service is noble—that, as much as or more than anything else, has given birth to it?

It is a singular fact that the Greek and the Roman, in spite of their great intellectual acuteness, accomplished so little in the penetration of Nature's secrets. With the strong love of the beautiful that distinguished the one, and the profound sense of law that marked the

other, one would have supposed that they would have felt more the charm and loveliness of the outward world, and have taken a greater interest in discovering its unchangeable ordinances. Is it unreasonable to refer much of this to that difference of religion which constitutes the most striking distinction between the classic and the Christian world? In the first place, the selfish isolation, the jealous individualism of ancient life, gave no encouragement to that sense of common interests among all mankind which is the justification of the scientist's pecuniarily unprofitable labors. Among the Greeks, while the feeling of devotion to the state, or rather city, was intense, the sentiment of the general welfare or the cause of humanity hardly existed. It was only with the advent of Christianity that the idea of mankind as one great family, each one of whom must labor for all the rest, came in. This idea has been the nurse, not only of modern civil freedom, but of modern science. "Not till the word barbarian was struck out of the dictionary of mankind," says Max Müller, in his "Lectures on the Science of Language," "not till the right of all nations of the world to be classed as members of one genus or kind was recognized, can we look even for the first beginning of our science. This change was effected by Christianity."

The grand thought that accompanied this sense of human brotherhood, forming the other pole of gospel truth, viz., the belief in one God and Father of men, gave an equal contribution toward supplying the intellectual soil needed for the prosperous growth of science. With the multitude of national and local gods, and even tribal or family divinities, which prevailed in the classic world, the minds of men were constantly diverted from that unity that is the scarlet thread in every royal cable of science. But monotheism, establishing unity in the divine realm, gave unity also to the order of Nature. While surrounding nations looked upon Nature in dread, and in blind superstition sacrificed their own little ones to the meteor or the volcano, the Hebrew, tracing all things up to the power of the eternal *I am*, beside whom there is no other god, found in all the forces and marvels of Nature fountains of good cheer and grateful praise. The earth was "the Lord's and the fullness thereof." "Dragons and all deeps, fire and hail, snow and vapor, stormy wind, fulfilling his word —all these were to praise the name of the Lord. For he commanded and they were created. He hath also established them forever and ever; he hath made a decree which shall not be moved" (Psalm cxlviii.). Christianity took up and diffused this grand view of the relation of Nature to God and to man. Though the appreciation of Nature's beauty, order, and dignity, was swamped for a time by the tide of Oriental asceticism, Grecian metaphysics, and transformed polytheism, it rose gradually above it, and established itself firmly in the mind of Christendom. It is this new interest in all the aspects, changes, and laws of the material, vegetable, and animal realms, full as

much as the propounding of the Baconian method, that has so adorned physical knowledge in these latter days; and when we consider what gave this new attraction to Nature, and shed over it a divine light, as it were, we can find no other agency so conspicuous, so powerful, as that of the two great religious dispensations, the record of which has been preserved for us in the Old and New Testaments. One whose name is among the very first on the rolls of science has given strong and explicit testimony on this point. Alexander von Humboldt, in a striking passage of his "Cosmos," sketching the intellectual phenomena of this world, thus describes the state of the Hebrew mind as distinguished from that exhibited among other portions of the human family: "It is characteristic of the poetry of the Hebrews that, as a reflex of monotheism, it always embraces the universe in its unity, comprising both terrestrial life and the luminous realms of space. The Hebrew poet does not depict Nature as a self-dependent object, glorious in its individual beauty, but always as in relation and subjection to a higher spiritual power. Nature is to him a work of creation and order—the living expression of the omnipresence of the Divinity in the visible world. Hence the lyrical poetry of the Hebrews, from the very nature of its subject, is grand and solemn, . . . and develops a rich and animated conception of the life of Nature. It might almost be said that one single psalm represents the image of the whole cosmos. We are astonished to find in a lyric poem of such limited compass the whole universe. . . . Similar views of the cosmos occur repeatedly in the Psalms, and most fully, perhaps, in the ancient if not ante-Mosaic book of Job."

Thus did religious reverence among the Hebrews lead to the notice and study of Nature. And, as to its influence on modern culture, let us listen again to the great philosopher of Berlin: "When the feelings died away," he continues, "which had animated classical antiquity and directed the minds of men rather to a visible manifestation of human antiquity than to a passive contemplation of the external world, a new spirit arose. Christianity gradually diffused itself, and, wherever it was adopted as the religion of the state, it not only exercised a beneficial condition on the lower classes by inculcating the social freedom of mankind, but also expanded the views of men in their communion with Nature. The eye no longer rested on the form of the Olympic gods. The Fathers of the Church, in their rhetorically correct and often practically imaginative language, now taught that the Creator showed himself great in inanimate Nature no less than in animated Nature; and in the wild strife of the elements no less than in the still activity of organic development. It was thus the tendency of the Christian mind to prove from the order of the universe and the beauty of Nature the greatness and goodness of the Creator, and *this tendency to glorify the Deity in his works gave rise to a taste for natural observation.*"

He who would assign, then, the sources of the modern scientific spirit cannot, without injustice, fail to assign a large measure of influence to Christianity.

Besides this general assistance to science from the religious spirit, the Christian Church, as an organization, although guilty of much hinderance, nevertheless has given much help. I believe, indeed, that in an impartial comparison the assistance which it has supplied would outweigh the injury which it has done. There was a time in the history of Europe we should not forget—when the fruit of all past knowledge and the seeds of future culture and enlightenment lay in the hands of the Christian clergy. For six centuries during the deluge of barbarism and ignorance which had submerged the ancient world, the Christian Church was the ark which rode upon the flood, bearing in its bosom whatever was most precious of the old-time learning and knowledge. Amid the devastations which attended the repeated waves of barbarian invasion, the greater part of Italy and France had become desolate and waste, dense with tangled forests, and haunted by wild beasts; and the arts of agriculture were not merely disused, but almost forgotten. By whom were these tracts and arts in Western Europe recovered for civilization? Mainly by the monks and priests. It is calculated that three-eighths of the cities and towns of France were born under the pioneership and protection of the monastic orders. The Benedictines, Mrs. Jameson says, were the first agriculturists who brought intellectual resources to bear on the cultivation of the soil, to whom we owe experimental farming and gardening, and the introduction of a variety of new plants.

Again, in the disorders occasioned by the fall of the Roman Empire, the imperial schools formerly scattered over Western Europe were extinguished, for an almost universal loss or destruction of books had occurred. It was only in the cloister and in the schools attached to the monasteries, established primarily for the study of the Scriptures, and conducted by the monks, that the light of knowledge was kept alive in Western Europe. The great universities of Europe, such as those of Paris, Bologna, Oxford, and Cambridge, are generally admitted to have had their origin in the schools attached to cathedrals and monasteries. Almost every one of the ancient and eminent seats of learning was either founded by the clergy or originally instituted for the purpose of fostering the study of the Scriptures.

Of course, the studies which occupied the first place were the Bible, the works of the Fathers, and theology in its various branches. But they were not limited to these. Science and art received attention, as well as sacred literature. Physics, chemistry, botany, medicine, law, painting, and the art of illumination, were all pursued within the walls of the cloister. A Benedictine monk, Guido d'Arezzo,

was the inventor of the gamut, and the first who instituted a school of music. The monks, it is claimed by high authorities, "were the parents of Gothic architecture, the inventors or improvers of the implements used in painting, the discoverers and preparers of some of the finest colors." "As architects, as glass-painters, as mosaic-workers, they were," says Mrs. Jameson, "the precursors of all that has yet been achieved in Christian art." Many of the distinguished pioneers of science belonged to the Church, or were educated in it. Among the alchemists, the forerunners of our chemists, Roger Bacon, Thomas Aquinas, Albertus Magnus, Raymond Lully, were ecclesiastics. Giordano Bruno in his early life was a Dominican priest; Gassendi and Copernicus held church offices, the former that of Professor of Theology, and afterward *prévôt* of a cathedral, and the latter a canonry and archdeaconship, and both remained faithful churchmen throughout their lives. Kepler was educated at the school of the monastery of Maulbron, and Boerhaave studied at Leyden for the sacred profession. This list, which a little research would easily enlarge, shows that, if there was a current in the Church antagonistic to scientific investigations, there was also a current that sympathized with it and impelled it onward.

Thus have science and religion given to each other assistance which more than balances, it seems to me, whatever hinderances they have put in each other's way. This assistance, to be sure, has been imperfect, has been more or less unconscious, and sometimes, perhaps, in despite of what has been intended. In the present controversy, as to the proper relations between science and religion, does not this page of history give useful instruction? Not to render them opponents, or maintain conflict between them by raking over the ashes of controversy; not to patch up a temporary truce by schemes for dividing the field of knowledge between them, but to continue and perfect between them this alliance of the past, making it henceforth a conscious, entire, and welcomed coöperation—is not this the duty of the present and the future? Since neither science nor religion can claim an exclusive sovereignty over the field of knowledge; since that domain cannot well be partitioned off between them, the true way is to unite them in a perpetual alliance. Take the testimony of both religion and science. Presume that there is a certain proportion of truth in what each has to offer. Weigh in the scales of reason what each presents. Accept that which is most solid, from whichever side it comes; or if neither, which is likely, presents the whole and real fact, employ the parallax of the two to give the actual position and full form of the two.

Each should seek from the other correction of its errors and filling out of its imperfections. Religion ought to obtain, from wider knowledge, greater purity and enlargement. She ought to learn from physical discovery the importance of going at once to facts and

thoroughly studying them, instead of sitting in her study patching dogmas out of scriptural shreds. She should learn from science the method of studying facts, as well as its importance, how to criticise, to sift, to throw away the chaff and keep only the solid grain. And, having mastered the secret of modern knowledge, she should proceed to put theology upon a solid inductive basis, and build it up into the genuine science of which it is capable.

And similarly science ought to obtain the help of religion to elevate and perfect it. From the ideal aspirations of faith science should enlighten its vision and ennoble its aims. It should not restrict its studies merely to the lower realm of facts. Science fails to fulfill its appointed mission in the world if it ceases its researches on the threshold of the grandest discoveries open to it, the questions above all in interest to humanity. It should learn from theology to study the laws of mind and soul as well as those of matter; to recognize that the fundamental truths of morality and religion are self-evident, as well as those of geometry, and that the belief in a God and in a future state is as primitive, universal, and necessary, as the belief in the uniformity of Nature or the indestructibility of force. It should look at the upraised finger of Faith and be pointed from the law to the Law-giver; from the effect to a cause; from the force to the living well.

To widen, purify, and make stable; to save from the building of unsubstantial air-castles, and from blind clasping of objects unworthy of worship—this is what science should do for religion.

To inspire and enable and crown; to turn from peering and picking altogether in the dust; to look up to the heavens—this is what religion should do for science. Playing no hostile nor rival, nor even independent strains—but each in sweet concord and divine respondence, joining in the same holy anthem—thus knowledge and reverence, mind and soul, all "according well, may make one music as before, but vaster."

## NATURE OF THE INVERTEBRATE BRAIN.

By Prof. H. CHARLTON BASTIAN.

### I.

NOTHING distinctly answering to a brain is to be found in the lowest animals in which a nervous system exists. It is thus, for instance, with star-fishes and the larger nematoid entozoa, in which what most nearly resembles a brain consists of a mere band of nerve-fibres surrounding the commencement of the œsophagus, and containing a few nerve-cells, partly between its fibres and partly in groups slightly removed therefrom.

The absence of distinct ganglia in the neighborhood of the mouth in star-fishes is doubtless due, in the main, to the form of these animals, and their low type of organization. Each arm or ray presents its own nervous system, and the ring or band round the mouth seems to be little more than a commissure connecting these otherwise distinct parts of the common system.

In the larger parasitic nematoids the nervous system is more concentrated. The œsophageal ring and immediately adjacent parts constitute almost all that is known of the nervous system in these organisms, and it contains, or is in relation with, a larger number of ganglion-cells than the similar part in star-fishes. Thus, in addition to the cells intermixed with the fibres of the ring itself, there are five or six groups adjacent to and in connection with it, which receive fibres from certain large papillæ surrounding the mouth and having a rudimentary tactile function. These papillæ are, in all probability, the nematoids' principal sensory organs. By means of the connecting nerve-fibres and ganglion-cells they are brought into relation with the nervous ring, and from this other outgoing fibres are, doubtless, given off to the four great longitudinal muscular bands by which the movements of the animal are effected. The distribution of these latter or motor nerve-fibres, however, has not been distinctly traced. The absence of ganglionic swellings on, or in connection with, the œsophageal ring of nematoids is probably dependent upon the comparative simplicity and limited number of impressions capable of being received through these cephalic papillæ.

We turn now to the nervous system, and to those parts of it, more especially, which answer to the brain of higher animals as it occurs in the three sub-kingdoms of the *Invertebrata*, containing its higher types of life. These sub-kingdoms are VERMES, ARTHROPODA, and MOLLUSCA.

Among representatives of the sub-kingdom *Vermes*, the nervous system varies a good deal in minor details, in accordance with the degree of organization, and with the diversity of the sensory and locomotor endowments of the several organisms. The broad features of the nervous system, however, are very similar in all.

The *Nemertidæ*, a class of marine worms, possess a nervous system of very simple type. They have soft and highly-contractile bodies, covered with cilia, but are otherwise wholly devoid of external appendages or traces of segmentation. On the anterior extremity of the body, a little posterior to the mouth, two, four, or more specks of pigment are met with, which are conjectured to serve the purpose of rudimentary ocelli, and while the animal is moving from place to place this anterior part of its body doubtless acts as its principal tactile surface. Nerve-fibres proceed from these regions, and converge so as to form three or four nerve-trunks on each side, which enter a comparatively large ganglionic mass lying on the lateral aspect

of the sheath of the proboscis. Each ganglion is pyriform in shape, and connected with its fellow by means of two commissures, one of which passes over, and the other underneath, the proboscis. It is difficult to trace the ultimate distribution of the nerve-fibres in these creatures; so that, although fibres can be followed nearly up to the pigment-spots, none have been detected in immediate continuity with them.

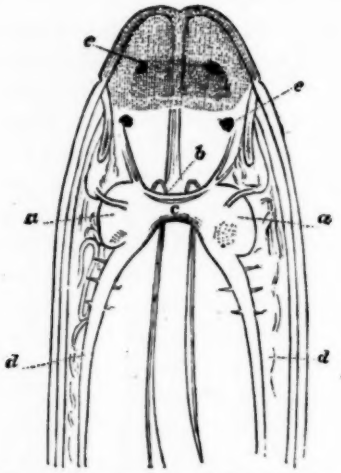


FIG. 1.—HEAD AND BRAIN OF NEMERTES.

The inferior commissure between the two ganglionic masses is shorter and broader than the upper, and, while it serves in part to bring the two ganglia into communication, it is also partly composed of commissural fibres, uniting the two great lateral nerve-trunks. These start from the ganglia, and, proceeding along the sides of the body, give off numerous branches to the longitudinal and circular muscles between which they are situated.

The pyriform ganglia are mostly of a pink or reddish color, and they are crowded with small nerve-cells. They represent the brain as it exists in these animals, and we have here, perhaps, a type of the simplest form which this organ could assume among active creatures possessing a distinct bilateral symmetry. Tactile and possibly gustatory impressions, together with impressions produced by light or darkness, doubtless come from the anterior extremity of the organism to the pyriform ganglia on either side, and are thence reflected along correlated channels in the great efferent bundles, proceeding to the muscles on one or both sides of the body, and also to the muscular proboscis. Other departments of the nervous system may exist in these animals, though as yet none have been detected.

In the common earthworm the nervous system is somewhat differently developed. The lateral ganglia of the *Nemertidæ* are replaced by two upper ganglia, connected by lateral commissures with

a single lower ganglion; and, as a consequence of the coalescence of the two lower halves, we have, instead of the two lateral cords of the *Nemertidæ*, a double ventral nervous cord traversing the whole length of the body. There are no distinct ocelli in the earthworm. The body is composed of a multitude of ring-like segments, each of which is provided with lateral setæ, which are called into play during the subterranean locomotions of the animal.

The double ventral cord has a fibrous structure along its upper surface, while below there is an irregular stratum of ganglion-cells. These cells are more abundant about the centre of each body-segment, and their aggregation gives rise to a series of rudimentary ganglia in these situations. From every one of the ganglionic swellings two nerves are given off on each side, while a third pair of nerves issues from the cord itself just anterior to the swelling, and is distributed along the anterior boundaries of the segment.

The œsophageal ganglia in the earthworm are, proportionately to the rest of the nervous system, much smaller than in the *Nemertidæ;* and this is perhaps due in great part to the existence of the numerous segmental ganglia in the former, which have no existence in the marine worms. The movements of the *Nemertidæ*, like those of the nematoids, are probably much more exclusively under the control of the œsophageal ganglia than are those of the segmented earthworm —in which each of the body-ganglia doubtless has much to do with bringing about the contraction of contiguous muscles. The earthworm has also a more complex visceral structure than is to be met with among the *Nemertidæ;* and, moreover, it presents more distinct evidences of a nervous interconnection between the different organs of the body and some of the principal nerve-centres. Lockhart Clarke has described a complicated ganglionic network on each side of the œsophagus, starting from the commissures and sending prolongations to the intestine and other parts. By means of this principal visceral system of nerves, the internal organs are brought into relation with one another, and with the nervous system of animal life—that is, with those parts having to do more especially with the relation of the organism to its medium.

The upper or supra-œsophageal ganglia, representing the brain of the earthworm, receive a nerve-trunk on each side, composed of fibres coming from the tactile upper lip, and, as no sensory filaments of a different order are known to be immediately connected therewith, the functions of the brain in this animal must be comparatively simple. This upper lip contains a certain amount of diffused pigment, though there are no signs of the existence of distinct ocelli. I have spoken of the part as a special organ of touch, but it is equally probable that it may be capable of receiving more special impressions representing rudimentary tastes. The separation between these modes of sensibility may in such low organisms be somewhat indefinite.

In the leech we meet with some variations in the arrangement of the nervous system, of a kind analogous to changes subsequently to be spoken of as occurring in higher forms of life. The nervous system becomes more concentrated. There is no longer a ganglion for each segment, but one for every three or four segments of the animal; and the two ventral cords approximate so closely as to be almost fused into one. In the common medicinal leech, for instance, there is a bilobed ganglion (*a*) above the mouth, which receives fibres from the tactile lips, and also ten distinct filaments from as many pigment-spots (*b b*) or ocelli, situated round the margin of this upper lip.

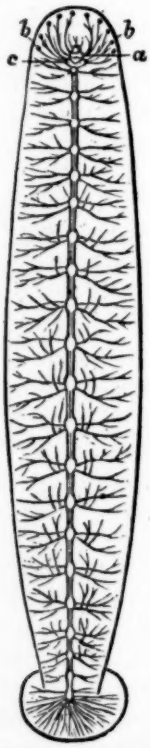


FIG. 2.—NERVOUS SYSTEM OF THE MEDICINAL LEECH.

From this bilobed ganglion, which corresponds with the brain proper of higher animals, a cord descends on each side of the œsophagus, and the two unite in a heart-shaped supra-œsophageal ganglion (*c*), from which afferent nerves are given off to the muscles whose business it is to move its three saw-like jaws, as well as to the muscles of the oral sucker. This lower ganglion in part corresponds with the "medulla oblongata" of vertebrate animals. It is continuous with the double ventral cord, on which twenty equidistant rhomboidal ganglia are developed. Each of these ganglia gives off two nerves

on either side, whose branches are distributed to the muscles and parietes of adjacent segments.

In this animal also a simple filament is given off from the posterior part of the supra-œsophageal ganglion, and is distributed along the dorsal aspect of the alimentary canal. It foreshadows an important system of nerves corresponding partly with that of the "sympathetic," and partly with the pneumogastric (or lung and stomach) nerves in higher animals. This system is known among invertebrates as the "stomato-gastric system." In other members of the invertebrate series it frequently takes its origin from the commissures connecting the upper and lower ganglia, rather than from the upper ganglion itself. The more complicated stomato-gastric system of the earthworm has an origin of this kind.

The kind of nervous system which pertains to the earthworm and to the leech exists, with only comparatively trivial variations, throughout the whole sub-kingdom *Vermes*.

The next sub-kingdom—the *Arthropoda*—comprises centipedes, crabs, spiders, and insects. They are all characterized by the possession of hollow and jointed organs of locomotion, containing distinct muscles, these appendages being represented among *Vermes* only by lateral setæ or bristles of different kinds. The lowest types of these various classes possess a nervous system closely analogous to that existing among the various kinds of worms. In the more complex types of crabs, spiders, and insects, however, we meet with a great increase in the complexity of animal organization, and this increase of complexity is shared in by the nervous system. Among insects, for instance, the respiratory organs assume a marvelous degree of elaboration, and the development of this system, together with a correlated development of their nervous and muscular systems, contributes greatly to the enormous powers of locomotion for which these denizens of the air are remarkable. The acuteness and structural elaboration of their sense-organs is almost sure to be greatly increased in such active creatures; and, looking to the nature of the intelligence in these lower animals, there is thus afforded an increasing stimulus to brain-development and slightly higher brain-functions.

Among the lower centipedes, such as *Iulus* and *Geophilus*, in which the limbs, though very numerous, are feeble and ill-developed, the nervous system exhibits only a slight advance over the forms which it presents among the higher *Annelida* (Fig. 3). But in the more powerful predatory forms, of which the common centipede may be taken as a type, a distinct advance is met with. This carnivorous animal has a smaller number of well-developed limbs, and its nervous system closely resembles that found among caterpillars or the larvæ of higher insects.

The supra-œsophageal ganglia receive nerves from the two pairs

of antennæ, and from the groups of ocelli on each side of the head, and they are connected by œsophageal cords with a bilobed infra-œsophageal ganglion, which distributes nerves to the jaws and other parts about the mouth. This bilobed infra-œsophageal ganglion is the first and largest of a series of ventral ganglia, numbering twenty-two in all, which are connected together by a double ventral cord. Every ganglion sends off nerves on each side to a pair of limbs.

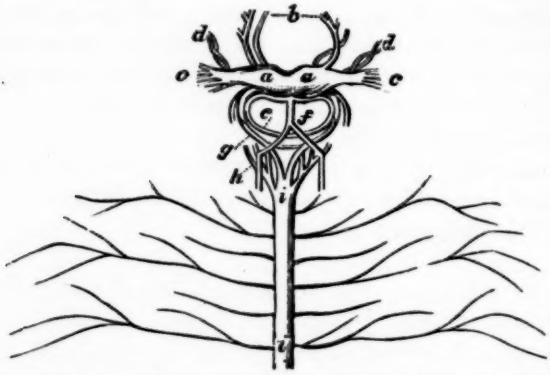


Fig. 3.—Brain and Adjacent Parts of Nervous System of Iulus.

From the posterior part of the brain, or from the œsophageal cords, the stomato-gastric nerves are given off, and distribute themselves over the alimentary canal in the usual manner.

Organs of vision become much more elaborate in crabs, spiders, and insects, than among worms or centipedes. And, while organs of touch and taste are further perfected in these higher arthropods, two new sensory endowments also become manifest. These organisms, or at least all the higher forms of them, are capable of being impressed by and of discriminating the different odors of some substances anterior to the contact of such substances with their gustatory surfaces. This new power aids them in their search for or recognition of food. Such organisms are, in addition, capable of appreciating those vibrations of the medium they inhabit, which induce in us impressions recognized as sounds or noises. In other words, they acquire a rudimentary power of hearing.

These additional sensory endowments are of high importance to all organisms, but more especially to those possessing active powers of locomotion—serving, as they do on the one hand, to help to bring their possessors into relation with food, and, on the other, to warn them of the approach of enemies, of friends, or of sexual mates.

Among *Crustacea* great differences are met with in the degree of concentration of the nervous system, the variations being in the main dependent upon differences of external form in the respective members of the class. In some of the lower terms of the series allied to

wood-lice (such as talitrus and oniscus), in which the body is elongated and composed of many almost similar segments, the nervous system is not very different from that of the more highly-organized worms.

In slightly higher forms of *Crustacea*, however, the two divisions of the originally double ventral cord approximate and become fused together, while, at the same time, the equality of its ganglia diminishes. Thus, in such forms as the lobster and the crayfish, the ganglia of the thorax which supply nerves to the limbs are distinctly larger than those of the abdominal segments, though these are also of good size, since the tail-segments are actively called into play during locomotion.

In the prawn a further development and concentration of the nervous system is seen. The thoracic ganglia are fused into a single elliptical mass, though those of the abdominal segments still remain separate.

But in the ordinary edible crab and its allies (Fig. 4), a still more remarkable concentration of the nervous system is met with. All the thoracic and all the abdominal ganglia are here fused into one large perforated mass of nervous matter (*c*), situated near the middle of the ventral region of the body.[1] From this large compound ganglionic mass nerves are given off to the limbs, to the abortive tail, and to other parts.

The brain of the crab (*a*) is represented by a rather small bilobed ganglion. It receives nerves from the pedunculated compound eyes, from the two pairs of antennæ, and from the palpi-bearing mandibles. The posterior antennæ (or antennules, as they are sometimes termed) contain in their basal joint a body which is supposed to represent an olfactory organ, though others have regarded it (on very insufficient grounds) as an organ of hearing. The rather small bilobed brain is, indeed, regarded by many naturalists as essentially composed of three pairs of ganglia, completely fused into one another, but in relation with the three pairs of sensory organs—the eyes, the tactile antennæ, and the supposed olfactory antennules. It is connected, by means of a long cord (*b*, *b*), on each side of the œsophagus, with the anterior extremity of the great ventral ganglion. These cords are long because of the absence of any separate sub-œsophageal ganglia, and because of the comparative distance of the great ventral nervous mass into the composition of which these ganglia enter. The great length of the œsophageal cords is one of the most notable characteristics of the nervous system of the higher *Crustacea*.

The "stomato-gastric" system of *Crustacea* is closely similar to that which exists in centipedes. One part of it is given off from the œsophageal cord on each side, while another median branch proceeds from the posterior part of the united cephalic ganglia, as in *Iulus* (Fig. 3, *f*).

[1] An artery passes through the perforation in this ganglion.

Among *Arachnida* forms of the nervous system exist which agree in many respects with those belonging to members of the class last described—these resemblances being in the main associated with certain general similarities of external form or configuration of body. Thus in scorpions the arrangement of the nervous system is not very dissimilar from that belonging to the prawn and its allies, since the thoracic ganglia have coalesced with one another and with the anterior abdominal ganglia, so as to form a large stellate nervous mass, which supplies the limbs and the anterior part of the abdomen. The ventral cord throughout the remainder of the abdomen and its caudal prolongation is marked at intervals by a series of small ganglionic swellings.

In spiders proper the nervous system attains its maximum of concentration. In addition to the abdominal and thoracic ganglia having all fused into one another and with the sub-œsophageal ganglion, we

FIG. 4.—NERVOUS SYSTEM OF A CRAB (*Pulmurus*).

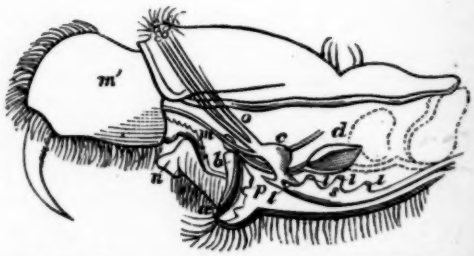


FIG. 5.—HEAD AND NERVOUS SYSTEM OF A SPIDER (*Mygale*).

find the large mass thus composed (Fig. 5, *s*) brought into extremely close relation with the cerebral ganglia or brain (*c*). They are connected by means of two stout commissures, one on each side of the very narrow œsophagus, whose small size is attributable to the suctorial habits of these carnivorous and predatory creatures. The captured fly is not eaten, its juices are sucked by the fierce spider by whom its life has been taken.

The bilobed brain of the spider receives nerves on each side (*o*), corresponding in number with the ocelli which the animal may possess. It also receives two large nerves (*m*) from the so-called mandibles, which are organs presumably developed from modified antennæ. These large nerves probably contain outgoing as well as ingoing fibres.

The sub-œsophageal ganglia correspond in the main, as we have already stated, with the medulla oblongata of vertebrate animals, and their fusion with the thoracic ganglia in the *Arachnida*, as well as in the *Crustacea* and *Myriapoda*, confirms the view held by some anatomists, that the medulla should be regarded as a prolongation of the spinal cord, rather than as an integral part of the brain.

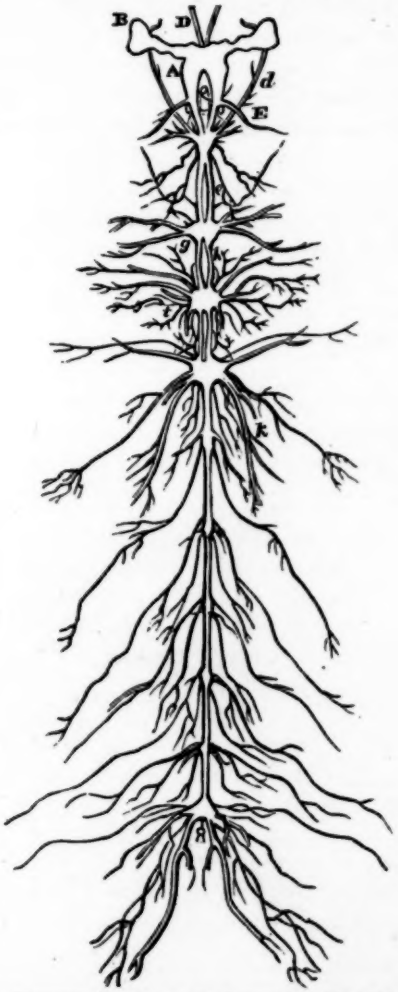


Fig. 6.—Nervous System of an Insect (*Acrida viridissima*).

The nervous system of insects varies not only among different classes and orders, but even in the same individual, in different stages of its development. The larva, or caterpillar, of a butterfly, for instance, presents a nervous system not very different from that met with in the centipede; while in the imago stage, or perfected insect, the same system has undergone some remarkable changes, leading to

increased size of the cerebral ganglia, and also to further development of some of the ganglia pertaining to the ventral cord, with concentration or even suppression of others.

In such insects as butterflies, bees, and dragon-flies, in which the visual organs are enormously developed, and in which the power of vigorous and sustained flight is correspondingly increased, the nervous system attains its maximum of development among the *Arthropoda*. The brain of these creatures differs from that existing in all other members of the class by reason of the great development of those portions of it in relation with the visual organs. A ganglionic swelling is frequently found where the nerve joins the brain (Fig. 6, *B*,) and in some insects there are also small ganglionic swellings at the corresponding parts of the antennal nerves.

As in spiders, the œsophageal ring is very narrow, owing to the greatly-diminished size of the œsophagus in the imago forms of higher insects. The double upper or cerebral ganglion is, however, connected in all insects with a separate sub-œsophageal ganglion, from which nerves are given off to the mandibles, the maxillæ, and the labium, though in spiders, crustaceans, and myriapods, as I have before stated, this part has no existence separate from the thoraçic ganglia.

In insects the three thoracic ganglia also often preserve a separate existence (Fig. 6), though in such higher types as I have named above

Fig. 7.—Brain and Adjacent Parts of Nervous System of the Privet Moth in the Pupa State.

these ganglia are more frequently fused into a single, lobed mass. The eight abdominal ganglia, which are always much smaller than the thoracic, continue to have a separate existence among some of the less developed types of insects, though it is more frequent for some, or even all, of them to disappear.

The stomato-gastric system also attains considerable complexity

in these animals. It is often connected anteriorly with a median frontal ganglion (Fig. 7, *E*), lying anterior to and below the brain, which supplies branches to the mouth and adjacent parts. This oral or frontal ganglion, besides being connected with the brain, also gives origin to a median recurrent nerve (*e*). This nerve is connected with other branches, proceeding from one or two pairs of lateral ganglia (*c*), near to, and taking origin from, the œsophageal cords. The system of nerves thus derived furnishes branches to the stomach, the intestines, and other viscera. In addition, we meet in insects with another well-developed set of visceral nerves, taking origin from a chain of minute ganglia, which lie upon and are connected with the large ventral ganglionated cord. These nerves are distributed to the extensive and greatly multiplied air-tubes, or respiratory organs. They are known to anatomists as "nervi transversi," and are much more developed in insects than are its representatives among any other class of arthropods.

## MODERN SCIENTIFIC GEOGRAPHY.[1]

By Dr. HERMANN J. KLEIN.

AMONG the various branches of natural science which have in recent times attained a high development, geography holds a prominent rank. By this, however, we must understand, not so much that vast regions of previously unexplored country have been made known to the educated world; that rivers, seas, and mountains, have been discovered, and the courses of known streams more accurately defined in maps; but rather that geotectonic[2] data, of which a rich store has been collected, have been studied from broad and general points of view, and the individual phenomena ranged in the order of cause and effect. In earlier times geography was simply a catalogue of facts, and the earth's surface an ultimate datum; but nowadays we are beginning to regard the superficies of our planet as a *result*, to investigate the relations between its separate parts, and to note the changes which occur in it. In the words of Karl Ritter: "Scientific geography by no means regards our planet as a lifeless, dead aggregate of an unorganized nature, or, as Herodotus expresses it, a disk turned on a lathe; but as a truly and specially organized body in steady process of development, bearing within itself the life-germs of further evolution. Herein consists its unity; and it is in virtue of this, its living principle, that it is a whole, lending itself to an orderly presentation and development of its great system. Furthermore, it is this which makes of it a science instructive to the human mind—an indispensa-

[1] Translated from the German by J. Fitzgerald, A. M.

[2] Relating to the earth's structure.

ble portion of the system of the sciences." True, even in this broad conception, Ritter conveys no adequate idea of what scientific geography is. His illustrious labors were restricted to a narrower field, and we may say that he worked only upon a part of the foundations

MAP OF THE MEDITERRANEAN SEA, SHOWING THE RELATIVE DEPTHS.

of the proud edifice which future ages will behold. Still, so far are we from wishing to discredit the important services rendered by this great geographer that we are free to confess that he achieved all that

was possible in his day. Scientific geography is dependent upon a number of other sciences, and its progress is conditioned upon the development of these. No other science is so ill adapted as geography to advance independently and without external aid. When the astronomer aims at new applications of the theory of disturbance, or when the physicist studies the phenomena of polarization; when the chemist undertakes to break up combinations of elements, or the geologist investigates the relations subsisting between different strata, each of these investigators labors in his own province, almost entirely without reference to the progress made in other departments of science. But when, on the contrary, a traveler, like the enterprising Lieutenant Cameron, traverses broad continental regions over unexplored paths, the gain to scientific geography from such undertakings in great measure depends upon the development of astronomy, meteorology, geology, etc., inasmuch as it is by the aid of these sciences that we can discuss the observations that have been made, and turn them to account for ulterior conclusions. Then, too, we must not overlook those sciences which have to do with organic Nature and which consider from higher points of view the distribution of living beings. Bearing all this in mind, we can readily perceive how intimate is the connection between geography and all the natural sciences. Hence it is that in earlier times the idea of scientific geography could hardly be entertained. At first geography offered little besides an imperfectly-arranged mass of descriptions of strange lands and curious things; next it gradually invaded the domain of statistical facts; then the relations of the history of man to the earth's configuration were recognized and elucidated; at last came scientific geography, which investigates the relations between the structure of the earth and the sum of all terrestrial phenomena, both organic and inorganic. The following instance will show the distinction between ordinary (descriptive) geography and scientific geography.

No inconsiderable part of the surface of *terra firma* consists of deserts, those vast, dry, and in part sandy regions, the type of which is the Sahara. The old descriptive geography gives the geographical situation of these wastes, their superficial extent, the number and site of their oases, the names of the mountain-regions which traverse them, and perhaps a few observations after the manner of anecdotes upon the intense heat which prevails in such regions, and the perils of a journey through the desert.

Scientific geography, on the other hand, regards these deserts as an integral part of the terrestrial organism, and shows how their occurrence is not accidental, but a necessary result of the past and present distribution of land and water, and of the position of the zone of calms. It exhibits to us the process of forming deserts still active, inasmuch as there exist centres of sand-radiation. It solves for us the enigma of the formation of springs in the oases, inasmuch as it

rejects as unverified the asserted absolute rainlessness of the deserts, and in the precipitated meteoric water finds a sufficient supply for the wells of the low-lying oases. With the aid of meteorology it shows how one continent tends to reduce another to the condition of a desert; and, taking man into the sphere of its observations, it discusses the influence of the soil and the configuration of a region upon the course of culture-development therein, and even upon the development of peculiarities of speech. Scientific geography in this way vivifies the dead superficies of our planet, and gives to the conventional lines of a map the power of speaking a language that is understood by the educated mind.

The endeavor to meet the requirements of a higher geography is also to be seen in the better style of our modern maps. Thus, whereas in former times the seas were represented by blank spaces surrounding the land, now we have the results of soundings carefully represented, and the lines of equal depths, as they are more or less parallel to the present contours of the coast, supply to the geographer valuable data with respect to the formation of the land itself. On looking at the sketch of the Mediterranean Sea, in which various depths from fifty to five hundred fathoms are represented, the reader will perceive far more clearly than he could from the mere contour of the coasts that, not taking the Black Sea into account, the Mediterranean Sea proper consists of two great basins, viz., a western basin, extending from Gibraltar to Cape Bon and the southwestern extremity of Sicily, and an eastern basin extending thence to the coast of Syria. The shallow depth between Africa and Sicily, and especially the track of the hundred-fathom line, shown in our map by a dotted curve, prove that, at a time not very remote geologically, Africa and Europe were much nearer to one another than they are now, and that in the still remoter past the two continents were connected at this point. In all probability this union existed at a period when as yet the present southern shore of the eastern Mediterranean basin had not been upheaved, and the sea covered a portion of what is now the Sahara. French investigators have supposed that the most recent retreat of the sea was from the Syrtis Minor; nay, that even in historic times the great Algerian Chotts were directly connected with the Mediterranean as an arm of that sea. But this hypothesis is negatived by G. Stache's discovery of a stratum characterized by land and fresh-water shells, at the base of the Quaternary formations which constitute the coast of the Gulf of Gabes.

If we take up a geological chart, e. g., the beautiful "General Map of the Sedimentary Formations of Europe," by H. Habenicht, we find nothing that contradicts these conclusions. Thus the Eocene formations, which are widely diffused over the northern extremity of Africa, and especially in Tunis, occur again in the island of Sicily, while the southern and the southwestern portion of that island show the most

recent Tertiary strata. These same strata form the coast of Syrtis Major, where yet the Mediterranean extends farthest southward, and where probably was situated the last channel through which water was supplied to the sea that once covered a portion of the Sahara. That here gradual upheavals of the land have taken place, each upheaval succeeded by a protracted season of repose, is shown by the terraces, the origin of which is so well known to the geologist. Gerhard Rohlfs found these terraces as he ascended the rising ground back of Tolmita, the ancient Ptolemais. He observes that these terraces are separated from one another by levels several miles in width.[1]

But if, turning aside from these geological considerations, we again glance at our map of relative depths, we almost everywhere find that a flat coast accompanies a shallow sea; while, on the other hand, a mountainous coast implies a sudden and precipitous inclination of the neighboring sea-bottom. This would more plainly appear if our map were on a larger scale, and had a greater number of depth-curves for the purpose of comparison. This fact might be accounted for by supposing that the comparatively sudden upheaval of the coast-hills was connected with a considerable depression of the neighboring sea-bottom, while the slow and periodic sinking of the flatter portions gave rise to submarine terraces. But, aside from this hypothesis, the representation of graduated submarine depths has a significance not to be misunderstood in geological, zoölogical, and botanical investigations.

Turning now from the sea to the land, we find in our best modern maps a number of figures indicating, as accurately as possible, the elevations; nay, even the attempt has been made, in the magnificent atlas of Switzerland, to show the elevations by means of equidistant curves. The Lehmann method of representing the surface of a country with equidistant level-lines would be, in many respects, of the highest service for the study of the earth's surface, but as yet it can be practically employed only in individual cases, partly from the want of materials, partly also on account of technical difficulties.

Cartography is a powerful aid to scientific geography, inasmuch as it arranges in true projection a great mass of heterogeneous materials, bringing it before the eye within small space, and thus making apparent relations which else could hardly be noticed. As for political geography, viz., the description of the various empires of the world, their area, provinces, population, etc., this we would regard rather as a branch of statistics than of geography proper.—*Gaea.*

[1] "Von Tripolis nach Alexandrien," 1. Bd., S. 169.

# PREDATORY AND INDUSTRIAL SOCIETIES.[1]

By HERBERT SPENCER.

A GLANCE at the respective antecedents of individual organisms and social organisms shows why the last admit of no such definite classification as the first. Through a thousand generations a species of plant or animal leads substantially the same kind of life; and its successive members inherit the acquired adaptations. When changed conditions cause divergences of forms once alike, the accumulating differences arising in descendants only superficially disguise the original identity—do not prevent the grouping of the several species into a genus; nor do wider divergences that began earlier prevent the grouping of genera into orders and orders into classes. It is otherwise with societies. Hordes of primitive men, dividing and subdividing, do, indeed, show us successions of small social aggregates leading like lives, inheriting such low structures as had resulted, and repeating those structures. But higher social aggregates propagate their respective types in much less decided ways. Though colonies tend to grow like their parents, yet the parent societies are so comparatively plastic, and the influences of new habitats on the derived societies are so great, that divergences of structure are inevitable. In the absence of definite organizations, established during the similar lives of many societies descending one from another, there cannot be the precise distinctions implied by complete classification.

Two cardinal kinds of differences there are, however, of which we may avail ourselves for grouping societies in a natural manner. Primarily we may arrange them, according to their degrees of composition, as simple, compound, doubly-compound, trebly-compound; and, secondarily, though in a less specific way, we may divide them into the predominantly predatory and the predominantly industrial—those in which the organization for offense and defense is most largely developed and those in which the sustaining organization is most largely developed.

We have seen that social evolution begins with small, simple aggregates; that it progresses by the clustering of these into larger aggregates; and that, after consolidating, such clusters are united with others like themselves into still larger aggregates. Our classification, then, must begin with societies of the first or simplest order.

We cannot in all cases say with precision what constitutes a simple society; for, in common with products of evolution generally, societies present transitional stages which negative sharp divisions. As the multiplying members of a group spread and diverge gradually, it

[1] Abridged from advance-sheets of the "Principles of Sociology," Part II., "The Induction of Sociology," Chapter X., "Social Types and Constitutions."

is not always easy to decide when the groups into which they fall become distinct. Here the descendants of common ancestors, inhabiting a barren region, have to divide while yet the constituent families are near akin; and there, in a more fertile region, the group may hold together until clusters of families remotely akin are formed—clusters which, diffusing slowly, are held by a common bond that slowly weakens. By-and-by comes the complication arising from the presence of slaves not of the same ancestry, or of an ancestry but distantly allied; and these, though they may not be political units, must be recognized as units sociologically considered. Then there is the kindred complication arising where an invading tribe becomes a dominant class. Our only course is to regard as a simple society one which forms a single working whole, unsubjected to any other, and of which the parts coöperate, with or without a regulating centre, for certain public ends. Here is a table, presenting, with as much definiteness as may be, the chief divisions and subdivisions of such simple societies.[1] . . .

We pass now to the classification based on unlikenesses between the kinds of social activity which predominate, and on the resulting unlikenesses of organization. The two social types thus essentially contrasted are the predatory and the industrial.

It is doubtless true that no definite separation of these can be made. Excluding a few simple groups, such as the Esquimaux, inhabiting places where they are safe from invasion, all societies, simple and compound, are occasionally or habitually in antagonism with other societies; and, as we have seen, tend to evolve structures for carrying on offensive and defensive actions. At the same time sustentation is necessary, and there is always an organization, slight or decided, for achieving it. But while the two systems in social organisms, as in individual organisms, coexist in all but the rudimentary forms, they vary immensely in the ratios they bear to one another. In some cases the structures carrying on external actions are largely developed; the sustaining system exists solely for their benefit, and the activities are militant. In other cases there is predominance of the structures carrying on sustentation; offensive and defensive structures are maintained only to protect them; and the activities are industrial. At the one extreme we have those warlike tribes which, subsisting mainly by the chase, make the appliances for dealing with enemies serve also for procuring food, and have sustaining systems represented only by their women, who are their slave-classes; while at the other extreme we have the type, as yet only partially evolved, in which the agricultural, manufacturing, and commercial

[1] Three elaborate tables are here given in the text of Spencer's work, classifying the social aggregates of mankind into "Simple Societies," "Compound Societies," and "Doubly-Compound Societies." We are compelled to omit them and the accompanying text for want of space.

organizations form the chief part of the society, and, in the absence of external enemies, the appliances for offense and defense are either rudimentary or absent. Transitional as are nearly all the societies we have to study, we may yet clearly distinguish the constitutional traits of these opposite types, characterized by predominance of the outer and inner systems respectively.

Having glanced at the two thus placed in contrast, it will be most convenient to contemplate each by itself.

As before pointed out, the militant type is one in which the army is the nation mobilized, while the nation is the quiescent army, and which, therefore, acquires a structure common to army and nation. We shall most clearly understand its nature by observing in detail this parallelism between the military organization and the social organization at large.

Already we have had ample proof that centralized control is the primary trait acquired by every body of fighting-men, be it horde of savages, group of brigands, or mass of soldiers. And this centralized control, necessitated during war, characterizes the government during peace. Among the uncivilized, there is a marked tendency for the military chief to become also the political head (the medicine-man being his only competitor); and in a conquering race of savages his political headship becomes fixed. Among semi-civilized, the conquering commander and the despotic king are the same; and they remain the same among the civilized down to late times. The connection is well shown where, in the same race, we find a contrast in the habitual activities and in the forms of government. Thus the powers of the patriarchal chiefs of Kaffre tribes are not great; but the Zulus, who have become a conquering division of the Kaffres, are under an absolute monarch. Of advanced savages, the Feejeeans may be named as well showing this relation between habitual war and despotic rule; the persons and property of subjects are entirely at the king's or chief's disposal. We have seen that it is the same in the warlike African states, Dahomey and Ashantee. The ancient Mexicans, again, whose highest profession was that of arms, and whose eligible prince became king only by feats in war, had an autocratic government, which, according to Clavigero, became more stringent as the territory was enlarged by conquest. Similarly, the unmitigated despotism under which the Peruvians lived had been established during the spread of the Inca conquests. And that race is not the cause, we are shown by this recurrence in ancient America of a relation so familiar in ancient states of the Old World.

The absoluteness of a commander-in-chief goes along with absolute control exercised by his generals over their subordinates, and by their subordinates over the men under them. All are slaves to those above, and despots to those below. This structure repeats itself in the accompanying social arrangements. There are precise gradations

of rank in the community, and complete submission of each rank to the ranks above it. We see this in the society already instanced, as showing, among advanced savages, the development of the militant type. In Feejee six classes are enumerated, from king down to slaves, as sharply marked off. Similarly in Madagascar, where despotism has been in late times established by war, there are several grades and castes. Among the Dahomans, given in so great a degree to bloodshed of all kinds, "the army, or, what is nearly synonymous, the nation," says Burton, "is divided, both male and female, into two wings;" and then, of the various ranks enumerated, all are characterized as legally slaves of the king. In Ashantee, too, where his officers are required to die when the king dies, we have a kindred condition. Of old, among the aggressive Persians, grades were strongly marked. So was it in warlike ancient Mexico. Besides three classes of nobility, and besides the mercantile classes, there were three agricultural classes down to the serfs—all in precise subordination. In Peru, also, below the Inca there were grades of nobility—lords over lords. Moreover, according to Garcilasso, in each town the inhabitants were registered in decades under a decurion, five of these under a superior, two such under a higher one, five of these centurions under a head, two of these under one who thus ruled a thousand men, and for every ten thousand there was a governor of Inca race; the political rule being thus completely regimental. Till lately, another illustration was furnished by Japan. That there were kindred, if less elaborate, structures in ancient militant states of the Old World, scarcely needs saying; and that like structures were repeated in mediæval times, when a large nation, like France, had under the monarch several grades of feudal lords, vassals to those above, and suzerains to those below, with serfs under the lowest, again shows us that everywhere the militant type has sharply-marked social gradations, as it has sharply-marked military gradations.

Corresponding to this natural government, there is a like form of supernatural government. I do not mean merely that, in the ideal other-worlds of militant societies, the ranks and powers are conceived as like those of the real world around, though this also is to be noted; but I refer to the militant character of the religion. Ever in antagonism with other societies, the life is a life of enmity, and the religion a religon of enmity. The duty of blood-revenge, most sacred of all with the savage, continues to be the dominant duty as the militant type of society evolves. The chief, balked of his vengeance, dies enjoining his successors to avenge him; his ghost is propitiated by fulfillment of his commands; the slaying of his enemies becomes the highest action; trophies are brought to his grave in token of fulfillment; and, as tradition grows, he becomes the god worshiped with bloody sacrifices. Everywhere we find evidence. The Feejeeans offer the bodies of their victims killed in war to the gods before cooking

them. In Dahomey, where the militant type is so far developed that women are warriors, men are almost daily sacrificed by the monarch to please his dead father; and the ghosts of old kings are invoked for aid in war by blood sprinkled on their tombs. The war-god of the Mexicans (originally a conqueror), the most revered of their gods, had his idol fed with human flesh; wars being undertaken to supply him with victims. And similarly in Peru, where there were habitual human sacrifices, men taken captive were immolated to the father of the Incas, the sun. How militant societies of old in the East similarly evolved deities, who were similarly propitiated by bloody rites, needs merely indicating. Habitually their mythologies represent gods as conquerors; habitually their gods are named "the strong one," "the destroyer," "the avenger," "god of battles," "lord of hosts," "man of war," and so forth. As we read in Assyrian inscriptions, wars were commenced by their alleged will; and, as we read elsewhere, peoples were massacred wholesale in professed obedience to them. How its theological government, like its political government, is essentially military, we see even in late and qualified forms of the predatory type; for, down to the present time, absolute subordination, like that of soldier to commander, is the supreme virtue, and disobedience the crime for which eternal torture is threatened.

Similarly with the accompanying ecclesiastical organization. Very generally, where the militant type is highly developed, the political head and ecclesiastical head are identical—the king, chief descendant of his ancestor, who has become a god, is also chief propitiator of him. It was so in ancient Peru; and in Tezcuco and Tlacopan (Mexico) the high-priest was the king's second son. The Egyptian wall-paintings show us kings performing sacrifices; as do also the Assyrian. Babylonian records harmonize with Hebrew traditions in telling us of priest-kings. In Lydia it was the same; Crœsus was king and priest. In Sparta, too, the kings, while military chiefs, were also high-priests; and a trace of the like original relation existed in Rome. A system of subordination, essentially akin to the military, has habitually characterized the accompanying priesthoods. The Feejeeans have an hereditary priesthood, forming a hierarchy. In Tahiti, where the high-priest was royal, there were grades of hereditary priests belonging to each social rank. In ancient Mexico the priesthoods of different gods had different ranks, and there were three ranks within each priesthood; and in ancient Peru, besides the royal chief priest, there were priests of the conquering race set over various classes of inferior priests. A like type of structure, with subjection of rank to rank, has characterized priesthoods in the ancient and modern belligerent societies of the Old World. The like mode of government is traceable throughout the sustaining organization also, so long as the social type remains predominantly militant. Beginning with simple societies, in which the slave-class furnishes the warrior-class

with necessaries of life, we have already seen that, during the subsequent stages of evolution, the industrial part of the society continues to be essentially a permanent commissariat, existing solely to supply the needs of the governmental-military structures, and having left over for itself only enough for bare maintenance. Hence, the development of political regulation over its activities has been in fact the extension throughout it of that military rule which, as a permanent commissariat, it naturally had. An extreme instance is furnished us by the ancient Peruvians, whose political and industrial governments were identical—whose kinds and quantities of labor, for every class in every locality, were prescribed by laws enforced by state officers—who had work legally dictated even for their young children, their blind, and their lame, and who were publicly chastised for idleness; regimental discipline being applied to industry just as our modern advocate of strong government would have it now. The late Japanese system, completely military in origin and nature, similarly permeated industry; great and small things—houses, ships, down even to mats—were prescribed in their structures. In the warlike monarchy of Madagascar, the artisan classes are all in the employ of government, and no man can change his occupation or locality, under pain of death. Without multiplication of cases, these typical ones, reminding the reader of the extent to which, even in modern fighting states, industrial activities are officially regulated, will sufficiently show the principle.

Not industry only, but life at large, is, in militant societies, subject to kindred discipline. Before its recent collapse, the government of Japan enforced sumptuary laws on each class, mercantile and other, up to the provincial governors, who must rise, dine, go out, give audience, and retire to rest at prescribed hours; and the native literature specifies regulations of a scarcely credible minuteness. In ancient Peru, officers "minutely inspected the houses, to see that the man, as well as his wife, kept the household in proper order, and preserved a due state of discipline among their children;" and householders were rewarded or chastised accordingly. Among the Egyptians each person had, at fixed intervals, to report to a local officer his name, abode, and mode of living. Sparta, too, yields an example of a society specially organized for offense and defense, in which the private conduct of citizens, in all its details, was under public control enforced by spies and censors. Though regulations so stringent have not characterized the militant type in more recent ages, yet we need but recall the laws regulating food and dress, the restraints on locomotion, the prohibitions of some games and dictation of others, to indicate the parallelism of principle. Even now, where the military organization has been kept in vigor by military activities, as in France, we are shown, by the peremptory control of journals and suppression of meetings, by the regimental uniformity of education,

by the official administration of the fine arts, the way in which its characteristic regulating system ramifies everywhere.

And then, lastly, is to be noted the theory concerning the relation between the state and the individual, with its accompanying sentiment. This structure, which adapts a society for combined action against other societies, is associated with the belief that its members exist for the benefit of the whole, and not the whole for the benefit of its members. As in an army the liberty of the soldier is denied, and only his duty as a member of the mass insisted on; as in a permanently encamped army, like the Spartan nation, the laws recognized no personal interests, but patriotic ones only; so in the militant type throughout the claims of the unit are nothing, and the claims of the aggregate everything. Absolute subjection to authority is the supreme virtue, and resistance to it a crime. Other offenses may be condoned, but disloyalty is an unpardonable offense. If we take the sentiments of the sanguinary Feejeeans, among whom loyalty is so intense that a man stands unbound to be knocked on the head, himself saying that what the king wills must be done; or those of the Dahomans, among whom the highest officials are the king's slaves, and on his decease his women sacrifice one another that they may all follow him; or those of the ancient Peruvians, among whom with a dead Inca, or great *curaca*, were buried alive his favorite attendants and wives that they might go to serve him in the other world; or those of the ancient Persians, among whom a father, seeing his innocent son shot by the king in pure wantonness, "felicitated" the king "on the excellence of his archery," and among whom bastinadoed subjects "declared themselves delighted because his majesty had condescended to recollect them"—we are sufficiently shown that, in this social type, the sentiment which prompts the assertion of personal rights, in opposition to the ruling power, scarcely exists.

Thus the trait characterizing the militant structure throughout is that its units are coerced into their various combined actions. As the soldier's will is so suspended that he becomes in everything the agent of his officer's will, so is the will of the citizen in all transactions, private and public, overruled by that of the government. The coöperation by which the life of the militant society is maintained, is a *compulsory* coöperation. The social structure adapted for dealing with surrounding hostile societies is under a centralized regulating system, to which all the parts are completely subject; just as in the individual organism the outer organs are completely subject to the chief nervous centre.

The traits of the industrial type have to be generalized from inadequate and entangled data. Antagonism, more or less constant with other societies, having been almost everywhere and always the condition of each society, a social structure fitted for offense and defense

exists in nearly all cases, and disguises the structure which social sustentation alone otherwise originates. Such conception as may be formed of it has to be formed from what we find in the few simple societies that have been habitually peaceful, and in the advanced compound societies which, though once habitually militant, have become gradually less so.

Already I have referred to the chiefless Arafuras, living in "peace and brotherly love with one another," of whom we are told that "they recognize the rights of property in the fullest sense of the word, without there being any authority among them than the decisions of their elders, according to the customs of their forefathers;" that is, there has grown up a recognition of mutual claims and personal rights, with voluntary submission to a tacitly-elected representative government, formed of the most experienced. Among the Todas, who "lead a peaceful, tranquil life," disputes are "settled either by arbitration" or by "a council of five." The amiable Bodo and Dhimals, said to be wholly unmilitary, display an essentially free social form. They have nothing but powerless head-men, and are without slaves or servants; but they give mutual assistance in clearing ground and house-building. There is voluntary exchange of services—giving of equivalents of labor. The Mishmis, again, described as quiet, inoffensive, not warlike, and only occasionally uniting in self-defense, have scarcely any political organization. Their village communities, under merely nominal chiefs, acknowledge no common chief of the tribe, and the rule is democratic. Crimes are judged by an assembly.

Naturally, few, if any, cases occur in which societies of this type have evolved into larger societies without passing into the predatory type; for, as we have seen, the consolidation of simple aggregates into a compound aggregate habitually results from war, defensive or offensive, which, if continued, evolves a centralized authority with its coercive institutions. The Pueblos, however, industrious and peaceful agriculturists, who, building their unique villages, or compound houses, containing 2,000 people, in such ways as to "wall out black barbarism," fight only when invaded, show us a democratic form of government. "The governor and his council are elected annually by the people." The case of Samoa, too, may be named as showing, to some extent, how, in one of these compound communities, where the warlike activity is now not considerable, decline in the rigidity of political control has gone along with some evolution of the industrial type. Chiefs and minor heads, partly hereditary and partly elective, are held responsible for the conduct of affairs; there are village parliaments and district parliaments. Along with this we find a considerably-developed sustaining organization separate from the political—masters, who have apprentices, employ journeymen, and pay wages; and, when payment for work is inadequate, there are even strikes, upheld by a tacit trades-unionism.

Passing to more evolved societies, it must be observed, first, that the distinctive traits of the industrial type do not become marked, even where the industrial activity is considerable, so long as the industrial government remains identified with the political. In Phœnicia, for example, "the foreign wholesale trade seems to have belonged mostly to the state, the kings, and the nobles. . . . Ezekiel describes the King of Tyrus as a prudent commercial prince, who finds out the precious metals in their hidden seats, enriches himself by getting them, and increases these riches by further traffic." Clearly, where the political and military heads have thus themselves become the heads of the industrial organization, the traits distinctive of it are prevented from showing themselves. Of ancient societies, to be named in connection with the relation between industrial activities and free institutions, Athens will be at once thought of; and, by contrast with other Greek states, it showed this relation as clearly as can be expected. Up to the time of Solon, all these communities were under either oligarchs or despots. The rest of them, in which war continued to be the honored occupation, while industry was despised, retained this political type; but in Athens, where industry was regarded with comparative respect, where it was encouraged by Solon, and where immigrant artisans found a home, there commenced an industrial organization, which, gradually growing, distinguished the Athenian society from adjacent societies, as it was distinguished from them by those democratic institutions that simultaneously developed.

Turning to later times, the relation between a social *régime* predominantly industrial and a less coercive form of rule, is shown us by the Hanse Towns, by the towns of the Low Countries, out of which the Dutch Republic rose, and in high degrees by ourselves, by the United States, and by our colonies. Along with wars less frequent, and these carried on at a distance; and along with an accompanying growth of agriculture, manufactures, and commerce, beyond that of Continental states more military in habit—there has gone in England a development of free institutions. As further implying that the two are related, as cause and consequence, there may be noted the fact that the regions whence changes toward greater political liberty have come are the leading industrial regions; and that rural districts, less characterized by constant trading transactions, have retained longer the earlier type, with its appropriate sentiments and ideas. In the form of ecclesiastical government we see parallel changes. Where the industrial activities and structures evolve, this branch of the regulating system, no longer, as in the predatory type, a rigid hierarchy, little by little loses strength, while there grows up one of a different kind; sentiments and institutions both relaxing. Right of private judgment in religious matters gradually establishes itself along with establishment of political rights. In place of a uniform belief imperatively enforced, there come multiform beliefs vol-

untarily accepted; and the ever-multiplying bodies espousing these beliefs, instead of being governed despotically, govern themselves after a manner more or less representative. Military conformity, coercively maintained, gives place to a varied non-conformity maintained by willing union.

The industrial organization itself, which thus, as it becomes predominant, affects all the rest, of course shows us in an especial degree this change of structure. From the primitive predatory condition, under which the master maintains slaves to work for him, there is a transition through stages of increasing freedom to a condition like our own, in which all who work and employ, buy and sell, are entirely independent; and in which there is an unchecked power of forming associations that rule themselves on democratic principles. Combinations of workmen, and counter-combinations of employers, no less than political societies and leagues for carrying on this or that agitation, show us the representative mode of government; which characterizes also every joint-stock company for mining, banking, railway-making, or other commercial enterprise. Further, we see that, as in the predatory type the military mode of regulation ramifies into all minor departments of social activity, so here does the industrial mode of regulation. Multitudinous objects are achieved by spontaneously-evolved combinations of citizens governed representatively. The tendency to this kind of organization is so ingrained that, for every proposed end, the proposed means is a society ruled by an elected committee headed by an elected chairman — philanthropic associations of multitudinous kinds, literary institutions, libraries, clubs, bodies for fostering the various sciences and arts, etc., etc.

Along with all which traits there go sentiments and ideas concerning the relation between the citizen and the state, opposite to those accompanying the predatory type. In place of the doctrine that the duty of obedience to the governing agent is unqualified, there arises the doctrine that the will of the citizens is supreme, and the governing agent exists merely to carry out their will. Thus subordinated in authority, the regulating power is also restricted in range. Instead of having an authority extending over actions of all kinds, it is shut out from large classes of actions. Its control over ways of living in respect to food, clothing, amusements, is repudiated; it is not allowed to dictate modes of production, nor to regulate trade. Nor is this all. It becomes a duty to resist irresponsible government, and also to resist the excesses of responsible government. There arises a tendency in minorities to disobey even the legislature deputed by the majority, when it interferes in certain ways; and their oppositions to laws they condemn as inequitable from time to time cause abolition of them. With which changes of political theory and accompanying sentiment is joined a belief, implied or avowed, that the combined actions of the social aggregate have for their end to maintain the

conditions under which individual lives may be satisfactorily carried on; in place of the old belief that individual lives have for their end the maintenance of this aggregate's combined actions.

These pervading traits, in which the industrial type differs so widely from the predatory type, originate in those relations of individuals implied by industrial activities, which are wholly unlike those implied by predatory activities. All trading transactions, whether between masters and workmen, buyers and sellers of commodities, or professional men and those they aid, are effected by free exchange. For some benefit which A's occupation enables him to give, B willingly yields up an equivalent benefit; if not in the form of something he has produced, then in the form of money gained by his occupation. This relation, in which the mutual rendering of services is unforced and neither individual subordinated, becomes the predominant relation throughout society, in proportion as the industrial activities predominate. Daily determining the thoughts and sentiments, daily disciplining all in asserting their own claims, while forcing them to recognize the correlative claims of others, it produces social units whose mental structures and habits mould social arrangements into corresponding forms. There results this type characterized throughout by that same individual freedom which every commercial transaction implies. The coöperation by which the multiform activities of the societies are carried on, becomes a *voluntary* coöperation. And while the developed sustaining system, which gives to a social organism the industrial type, acquires for itself, like the developed sustaining system of an animal, a regulating apparatus of a diffused or uncentralized kind, it tends also to decentralize the primary regulating apparatus, by making it derive from more numerous classes its deputed powers.

Necessarily the essential traits of these two social types are in most cases obscured, both by the antecedents and by the coexisting circumstances. Every society has been, at each past period, and is at present, conditioned in a way more or less unlike the ways in which others have been and are conditioned. Hence, the production of structures, characterizing one or other of these opposed types, is, in every instance, furthered, or hindered, or modified, in a special manner. Observe the several kinds of causes.

There is, first, the deeply-organized character of the particular race, coming down from those prehistoric times during which the diffusion of mankind, and differentiation of the varieties of man, took place. Very difficult to change, this must in every case qualify differently the tendency toward assumption of either type.

There is, next, the effect due to the immediately preceding mode of life and social type. Nearly always the society we have to study contains decayed institutions and habits belonging to an ancestral

society otherwise circumstanced; and these pervert, more or less, the effects of circumstances then existing.

Again, there are the peculiarities of the habitat in respect of contour, soil, climate, flora, fauna, severally affecting in one mode or other the activities, whether predatory or industrial; and severally hindering or aiding, in some special way, the development of either type.

Yet further, there are the complications caused by the particular organizations and practices of surrounding societies. For, supposing the amount of offensive or defensive action to be the same, the nature of it depends in each case on the nature of the antagonist action; and hence its reactive effects on structure vary with the character of the antagonist. Add to this that direct imitation of adjacent societies is a factor of some moment.

There remains to be named an element of complication more potent perhaps than any of these—one which of itself often goes far to determine the type as predatory, and which in every case profoundly modifies the social arrangements. I refer to the mixture of races, caused by conquest or otherwise. We may properly treat of it separately under the head of social constitution—not, of course, constitution politically understood, but constitution understood as referring to the relative homogeneity or heterogeneity of the units constituting the social aggregate.

Inevitably as the nature of the aggregate, partially determined by environing conditions, is in other respects determined by the natures of its units, where its units are of diverse natures, the degrees of contrast between the two or more kinds of them, and the degrees of union between them, must greatly affect the results. Are they of unallied races, or of races near akin? and do they remain separate, or do they mix?

If units of two kinds are joined in the same society, their respective tendencies to evolve structures more or less unlike in character must modify the product. And the special modification will in every case further or hinder the evolution of one or the other social type. Clearly, where it has happened that a conquering race, continuing to govern a subject race, has developed the predatory regulating system throughout the whole social structure, and for ages habituated its units to compulsory coöperation—where it has also happened that the correlative ecclesiastical system, with its appropriate cult, has given to absolute subordination the religious sanction—and especially where, as in China, each individual is moulded by the governing power and stamped with the appropriate ideas of duty which it is heresy to question, it becomes impossible for any considerable change to be wrought in the social structure by other influences. It is the law of all organization that as it becomes complete it becomes rigid. Only where incompleteness implies a remaining plasticity is it possible for

the type to develop from the original predatory form to the form which industrial activity generates.

Especially where the two races, contrasted in their natures, do not mix, social coöperation implies a compulsory regulating system; the military form of structure, which the dominant impose, ramifies throughout. Ancient Peru furnished an extreme case; and the Ottoman Empire may be instanced. Social constitutions of this kind, in which aptitudes for forming unlike structures coexist, are manifestly in states of unstable equilibrium. Any considerable shock dissolves the organization; and, in the absence of unity of tendency, reëstablishment of it is difficult, if not impossible. In cases where the conquering and conquered, though widely unlike, intermarry extensively, a kindred effect is produced in another way. The conflicting tendencies toward different social types, instead of existing in separate individuals, now exist in the same individual. The half-caste, inheriting from one line of ancestry proclivities adapted to one set of institutions, and from the other line of ancestry proclivities adapted to another set of institutions, is not fitted for either. He is a unit whose nature has not been moulded by any social type, and therefore cannot, with others like himself, evolve any social type. Modern Mexico and the South American republics, with their perpetual revolutions, show us the result.

It is observable, too, that, where races of strongly-contrasted natures have mixed more or less, or, remaining but little mixed, occupy adjacent areas subject to the same government, the equilibrium maintained so long as that government keeps up the coercive form shows itself to be unstable when the coercion relaxes. Spain, with its diverse peoples, Basque, Celtic, Gothic, Moorish, Jewish, partially mingled and partially localized, shows us this result.

Small differences, however, seem advantageous. Sundry instances point to the conclusion that a society formed from nearly-allied peoples, of which the conquering eventually mingles with the conquered, is relatively well fitted for progress. From their fusion results a community which, determined in its leading traits by the character common to the two, is prevented by their differences of character from being determined in its minor traits—is left capable of taking on new arrangements determined by new influences: medium plasticity allows those changes of structure constituting advance in heterogeneity. One example is furnished us by the Hebrews, who, notwithstanding their boasted purity of blood, resulted from a mixing of many Semitic varieties in the country east of the Nile, and who, both in their wanderings and after the conquest of Palestine, went on amalgamating kindred tribes. Another is supplied by the Athenians, whose progress had for antecedent the mingling of numerous immigrants from other Greek states with the Greeks of the locality. The fusion by conquest of the Romans with other Aryan tribes, Sabini, Sabelli,

and Samnites, preceded the first ascending stage of the Roman civilization. And our own country, peopled by different divisions of the Aryan race, and mainly by varieties of Scandinavians, again illustrates this effect produced by the mixture of units sufficiently alike to coöperate in the same social system, but sufficiently unlike to prevent that social system from becoming forthwith definite in structure.

Admitting that the evidence where so many causes are in operation cannot be satisfactorily disentangled, and claiming only probability for these inductions respecting social constitutions, it remains to point out their analogy to certain inductions respecting the constitutions of individual living things. Between organisms widely unlike in kind, no progeny can arise: the physiological units contributed by them respectively to form a fertilized germ cannot work together so as to produce a new organism. Evidently as, while multiplying, the two classes of units tend to build themselves into two different structures, their conflict prevents the formation of any structure. If the two organisms are less unlike in kind—belonging, say, to the same genus though to different species—the two structures which their two groups of physiological units tend to build up being tolerably similar, they can, and do, coöperate in making an organism that is intermediate. But this, though it will work, is imperfect in its latest-evolved parts: there results a mule incapable of propagating. If, instead of different species, remote varieties are united, the intermediate organism is not infertile; but many facts suggest the conclusion that infertility results in subsequent generations: the incongruous working of the united structures, though longer in showing itself, comes out ultimately. And then, finally, if, instead of remote varieties, varieties nearly allied are united, a permanently-fertile breed results; and, while the slight differences of the two kinds of physiological units are not such as to prevent harmonious coöperation, they are such as conduce to plasticity and unusually vigorous growth.

Here, then, seems a parallel to the conclusion indicated above, that hybrid societies are imperfectly organizable—cannot grow into forms completely stable; while societies that have been evolved from mixtures of nearly-allied varieties of man can assume stable structures, and have an advantageous modifiability.

We class societies, then, in two ways; both having to be kept in mind when interpreting social phenomena:

First, they have to be arranged in the order of their integration, as simple, compound, doubly-compound, trebly-compound. And, along with the increasing degrees of evolution implied by these ascending stages of composition, we have to recognize the increasing degrees of evolution implied by growing heterogeneity, general and local.

Much less definite is the division to be made among societies according as one or other of their great systems of organs is supreme.

Omitting those lowest types which show no differentiations at all, we have but few exceptions to the rule that each society has structures for carrying on conflict with other societies and structures for carrying on sustentation; and the ratios between these admitting of all gradations, it results that no specific classification can be based on their relative developments. Nevertheless, as the predatory type, characterized by predominance of the one, is framed on the principle of compulsory coöperation, while the industrial type, characterized by predominance of the other, is framed on the principle of voluntary coöperation, the two types, when severally evolved to their extreme forms, are diametrically opposed; and the contrasts between their traits are among the most important with which sociology has to deal.

Were this the fit place, some pages might be added respecting a possible future social type, differing as much from the industrial as this does from the predatory—a type which, having a sustaining system more fully developed than any we know at present, will use the products of industry neither for maintaining a predatory organization nor exclusively for material aggrandizement; but will devote them to the carrying on of higher activities. As the contrast between the predatory and the industrial types is indicated by inverting the belief that individuals exist for the benefit of the state into the belief that the state exists for the benefit of individuals, so the contrast between the industrial type and the type likely to be evolved from it is indicated by the inversion of the belief that life is for work into the belief that work is for life. But we are here concerned with inductions derived from societies that have been and are, and cannot enter upon speculations respecting societies that may be. Merely naming as a sign the multiplication of institutions and appliances for intellectual and æsthetic culture, and for kindred activities not of a directly life-sustaining kind, but of a kind having gratification for their immediate purpose, I can here say no more.

Returning from this parenthetical suggestion, there remains the remark that to the complications caused by the crossings of these two classifications have to be added the complications caused by the unions of races widely unlike or little unlike; which here mix not at all, there partially, and in other cases wholly. Respecting these kinds of constitutions, we have considerable warrant for concluding that the hybrid kind, essentially unstable, admits of being organized only on the principle of compulsory coöperation; since units much opposed in their natures cannot work together spontaneously. While, conversely, the kind characterized by likeness in its units is relatively stable; and under fit conditions may evolve into the industrial type, especially if the likeness is qualified by slight differences.

# ORGANIZED HOMESTEADS AND HOUSEHOLDS.[1]

By WILLIAM F. CHANNING, M. D.

THE problem of homes for the people is not a simple one. The question is not merely how to house single families at the least cost. No solution of the problem can be worse than the solitary farm-house in a thinly-settled country. The real question is, how to reconcile the autonomy of the individual and family with the economies and productive forces of modern society. The solitary farm-house is a pioneer in the wilderness, and good for that. But the first generation born in it, or as soon as civilization has spread far enough to take it in, fly from it as if it were a pest-house. In the older States our population is rushing into the towns, not because the earth has grown barren, or because our town-life is natural or beautiful, but because modern civilization attracts and marshals mankind to coöperative work, and the universal instinct revolts against anti-social methods and solutions. More farmers and farmers' wives, in proportion to the population, are insane, than any other industrial or professional class in America; and this, notwithstanding all the healthful influences of Nature in the country, and the miasm, filth, and imprisonment, of the towns.

The first step toward social order is to secure the independent existence of the individual or family in a home which, like the traditional English house, shall be a castle inviolable and safe from all intrusion. One of the chief conditions of such independence is that the home shall be *owned* by the individual or family, *not rented.* On this account it introduces the wildest confusion into the present discussion to compare the working-men's houses in Philadelphia, owned by themselves, with hired tenements. We are brought, however, at once to a legitimate though limited ground of preference for the Philadelphia plan of purchasing a homestead, over the common method of living in rented houses, or in hired rooms in a tenement-house.

But this is only half of the question. The wastefulness of building a separate house for each family, even with the cheapest appliances, and of carrying on the household afterward, *will be always sufficient to make the difference between comfort and pauperism for the masses.* In other words, which will bear repetition, the separate house does not, cannot avail itself of the social economies and productive forces which are the means of modern civilization. Two great departments of human industry, *Agriculture, already alluded to, and the Household, remain in the hand-loom state of development.*

What is needed in agriculture to charm the population back to

[1] A paper read before the American Social Science Association at Philadelphia, June 1, 1876.

the fields, and to double the production of the soil, is to substitute suitable buildings at the centre of an agricultural township for unsuitable, straggling farm-houses and barns, and to replace solitary labor on farms by the modern method of organized industry, applied to the cultivation of a domain *large enough* to permit *selection of soils* and the use of *adequate machinery*. This question, "How can we keep the boys on the farm?" has just received a thoughtful answer from Colonel George E. Waring, in an "Ogden Farm-Paper," in the April number of the *American Agriculturist*.

What we need, in order to harmonize our household system with other branches of modern industry, is a *Federative Homestead, owned by those inhabiting it*, in which the great entries or halls may be considered as *streets under cover*, and the individual or family domiciles, *houses under a common roof*. For such buildings a new architecture and new machinery are needed. The Peabody tenement-houses in London, the family club-houses in England and on the Continent, the family hotels in this country, and the Familistère at Guise, though furnishing valuable architectural suggestions, have solved as yet but few of the problems of construction of the "People's Palace," as it has been called. Invention also has done comparatively little to furnish labor-saving machinery for agriculture and the household on account of the segregated and slovenly character of these industries.

The most obvious form of the People's Palace in the town is a hollow square, surrounded with streets, with inclosed and surrounding gardens—the space in the centre being large enough to give air and a pleasant outlook to the inner domiciles. To further this object, one side of the square might be left open, or devoted to work-rooms, only a single story in height. In the country the building might take the form of a cross, giving an open view on all sides with public rooms and halls, or a conservatory under glass (a winter garden) in the middle, and gardens surrounding.

The economies would increase, and also the independence of the occupants, with the increase of numbers within certain limits. While the edifice might be of equal size for rich or poor, the separate domiciles would naturally be smaller and more numerous where the means of the proprietors were less. In the same building the various domiciles would differ in value according to situation and size, and thus would suit persons of different means. Not less than one hundred nor more than four hundred families may be assumed for illustration as probable limits of number.

A building of architectural beauty, favorably situated in country or town, to contain one hundred domiciles, would cost, including land, not more than two-thirds as much as one hundred separate houses of the same class, giving to each family the same amount and quality of habitable room. The edifice should be fire-proof, safer from intrusion, better drained, better ventilated, freer from offenses of all kinds, than

the solitary houses. A finely-appointed kitchen, laundry, heating, lighting, and elevating apparatus, with telegraphic and other means of communication, sufficient for the wants of a hundred families, would replace one hundred sets of inferior work-rooms and apparatus in the separate houses. But one or more work-rooms would be provided in each domicile for minor or exceptional use.

The cost of carrying on the People's Household, including warming, lighting, water and food supply, cooking, and the laundry, with superintendence and general service, would not be *more* than two-thirds the cost of living in separate houses of the same class, all purchases being made at wholesale, and the work being performed by organized labor, using the best machinery. Each individual or family would be charged (perhaps against a monthly advance) for precisely what they consumed. The difference of cost between meals served in family alcoves of a great hall, or by dumb-waiter, or equivalent machinery, in each domicile, would be small, and, like all other arrangements, at the option of each proprietor. In previous experiments of this general character, it has not been found that any family would long prefer the more costly and inferior method of private purchase and labor in the departments of cooking and washing, although provision could easily be made for a limited use of the public machinery by individuals having such preference.

This estimate leaves to the women of each family the greater part of their time. Here is one of the greatest existing wastes of labor. *The separate house necessarily and permanently dooms woman to drudgery.* Under the present system she necessarily carries on a hundred trades every day by hand-work, as wasteful of productive force as the old spinning-wheel. The labor of women, saved in this way, would find new channels. The steam-power in the unitary building, in constant use for elevators, pumping, washing, cooking, heating, lighting, would always furnish a surplus of motive power for sewing-machines and small industries which would naturally grow up. In the People's Palace a Kindergarten for the youngest children, and schools more or less industrial and technical for those older, would have a natural and inevitable place. While this would still further relieve the mothers, it would also be a field for the occupation of women and men living in the Homestead who were specially gifted in these directions. Other collective work of the People's Home would give occupation to some of the inmates. Halls for lectures and social purposes, a library and reading-room, would also be among the endowments of every People's Palace.

Rising higher in the social scale, the question of domestic service, now so difficult of solution, would be summarily settled. In palatial buildings, occupying with inclosed and surrounding gardens a whole city square, erected with the wealth of a hundred rich families, nine-tenths of all the work would be done by the collective labor of em-

ployés, who would have no personal relations or contact with the individual proprietors. The remaining one-tenth of domestic service would admit of such selection and improvement of present methods as to get rid of the principal part of the evil. It is much easier to drill and actuate a corps of one hundred operatives in a public service than to direct a single domestic; and the elements of personal collision and suffering self-respect, inseparable from the latter rule, are absent from the former.

The Federative Homesteads, or People's Palaces, would especially need "Building Associations" for their establishment. But these associations would be neither charitable nor speculative; they would be mutual-insurance companies, not for rebuilding houses destroyed by fire, but to build each a palace, as perfect as modern art could make it, for the occupancy of its members, and subsequently to carry on the Palatial Household. The comparison of the Philadelphia system of separate houses, poorly constructed, and purchased by installments from building corporations not always purely mutual, should be made with such collective, self-owned homesteads, not with hired tenements, even should these be on the scale and with the appliances of the Peabody tenement-houses in London, erected by a magnificent charity.

The People's Palace, to replace the people's hovels, is no fanciful project or arbitrary contrivance, but the natural, inevitable form of the household required by our civilization, *corresponding strictly* with all our improved methods of productive industry; corresponding also with the social instincts and convictions of the time in which we live. Opposed to its practical introduction is the want of intelligence and mutual confidence in the masses, and also a selfish and exclusive spirit, which is short-sighted and defeats its own end. Witness the insecurity and ruinous waste of our separate households, the drudgery of women, and the slavery to servants. In agriculture witness also the loss of at least one-half the natural product by incoherent labor in the fields, and by the isolated farm-house and barn.[1]

I began this presentation of the "People's Palace" with the demand for an architecture and structural law which should throw around each individual and family a fortress of privacy, and which should secure a home-sphere more inviolable than is possible in our isolated houses, invaded daily by a horde of carriers, and pervaded by an alien caste of servants. This largest freedom and independence of the individual and family can only be assured by the perfect organization of the Homestead and Household.

In the vegetable and animal kingdoms the law of organization requires—1. The establishment of each individual molecule or cell in

[1] Reference is here due to an American sociological novel, entitled "Papa's Own Girl," by Marie Howland, which furnishes a vivid description of the Familistère at Guise, and its supposed adoption in this country.

a world of its own; 2. The coördination and coöperation of such atoms or cells with each other, in a collective body or organism, according to their precise form and place. The want of either of these factors, the distinct individual units, or the scientific grouping and marshaling of units in a collective unity, deprives a body of its place in the organic world. The same factors must enter into every social organization which is entitled to the name. We have in this country an example of a true organization in our federative political system, composed of townships, counties, States, and nation, with its motto, "Out of many, one." I have drawn thence the designation *Federative* for the organized Homestead.

It is essential that relations of precise equity shall prevail between the proprietors of a Collective Home. The right of individual property in each domicile should be fortified by separate title and right of sale, subject only to chartered restrictions. In a well constructed and organized Federative Homestead such domiciles would always be salable at full cost value. A precise account, based on accurate standards of measurement, must be kept with each individual or family, including both general and special supplies and services. Instruction in the schools of the Palace would be classed among services to be specially accounted for. Our present common-school system (the best of our institutions) is a violation of social organic law, on the side of communism, to balance its violation in the opposite direction by incoherent industry and incoherent homes. The only scientific justification, if it may be so called, of the present system, is the rule that two wrongs make a right. The relation of highly-organized societies to children will, without doubt, be parental, through the recognition of new equities and the extension of mutual affection and service. But the further consideration of this subject does not belong here.

There are two extremes of reaction against existing society: one, Communism, its destructive fusion; the other, Individual Sovereignty, its destructive analysis. Each tends to social dissolution, because it rejects one of the organic factors. Between these extremes—occupying the domain of organization—are two possible social orders, one constructive, attractive in all its forces, coöperative, in harmony with modern thought, and with the development of science and the arts. The People's Palace is the natural form of household belonging to this order. The other is an inverted organization, compulsory, actuated by destructive rivalries, characterized by speculation and fraud, and feudal in its tendencies and results. To this latter order, the middle-age civilization of Europe and America, which still holds us, belong the isolated house and all in our present methods which insulate instead of associating the industries, and reconciling the interests of mankind. The single but sufficient means of resisting the communistic dissolution of our present society is to substitute

everywhere for inverted methods natural organization, or, in other words, *scientific coöperation.*

The claim that the Federative Home, or "People's Palace," is the natural, inevitable form of the organized Household—coextensive with the future society—brings the subject within the domain of legitimate *social science.* The consideration of improved expedients for housing the people, without regard to the essential form and tendencies of civilization, is no part of social science, but only a discussion of the arts of life.

## RELATIONS OF HOSPITALS TO PAUPERISM.[1]

By W. GILL WYLIE, M. D.

CIVILIZATION has not reached that state of perfection where hospitals can be dispensed with. 1. As long as armies exist, hospitals will be necessary. Soldiers when sick must be provided with special accommodations; and, after a battle, the wounded cannot be properly cared for except in hospitals constructed especially for the purpose. 2. During epidemics of contagious and infectious diseases, it becomes a necessity to separate those infected from the well, and for their accommodation hospitals must be erected. 3. In every community, especially in large cities, there are always a certain number of paupers without any *homes*, who must be cared for when sick, and the only practical way of providing for them is to establish hospitals. 4. In large cities provision must be made for street casualties, and hospital accommodations are necessary. 5. On account of difficulty in making suitable provision for the insane in private houses, hospitals or asylums for the insane are necessary.

In this country, in all large cities, any one representing himself as poor and sick can apply either to the public hospitals supported by the State or to hospitals supported by voluntary contributions, and is admitted in many cases without any special inquiry or investigation as to his circumstances. In some places—as New York City—hospitals are so numerous, and admission to them so freely granted, that there is little or no restraint on impostors. If refused admission to one institution, they go to another and receive treatment and care without cost, when they are fully able to provide for themselves. And so numerous are the dispensaries where medicines and medical advice can be obtained free of cost, merely for the asking, and so easy and readily can care and attention be had in free hospitals, that the poor have no necessity to make provision for sickness.

It is estimated that about $10,000,000 are expended in public and

[1] Extract from Boylston Medical Prize Essay, Harvard University, on "Civil Hospital Construction," 1876.

private charities annually in the city of New York, a city of 1,000,000 inhabitants. A considerable portion of this sum is expended on the hospitals, which alone contain more than 6,000 *beds*, not including insane or other asylums, but only institutions known by the name of hospitals. About 4,000 of the 6,000 beds are in public city or State hospitals, the remaining 2,000 being in hospitals supported by voluntary charity. The official reports of the thirty-odd free dispensaries give 307,060 as the number of patients applying for and receiving treatment in 1875 at the dispensaries, against 20,631 treated at their homes.

To say that $10,000,000 are expended in charities, that there are 6,000 free beds in the hospitals, and that over 300,000 persons receive medicine and medical advice free of cost at the dispensaries, is certainly evidence of the generosity and Christian spirit of charity that prevail. But, when looked at in a direct, practical way, these figures show something else. If these official reports are to be relied upon, then, in a population of 1,000,000, over 300,000 persons receive alms every year. We doubt if the number of individuals is so large, for it is the custom of some dispensaries to count each visit a patient makes as a patient treated. But the actual number is immense, and increasing out of all proportion to the increase of population. The truth is, the majority of our hospitals, *as they are at present managed*, are liable to do more harm than good. Apparently they do much good, and for the time do relieve suffering and want, but in the end may do much harm. Giving help too readily even during sickness is hurtful, and when it is offered freely without the certain knowledge that it is really needed, it very naturally removes the healthful stimulus of necessity, the dread of which prompts every individual to provide for the misfortune of sickness.

The dispensaries as they are now managed are nothing less than a promiscuous charity, exactly similar to the notorious "soup-kitchen"—medicine being substituted for soup. They offer to the ignorant and poor an easy and ever-ready inducement to take alms. They are the first stepping-stones to the degradation of pauperism. The self-respect of an individual is injured the moment he accepts alms, and a habit of taking alms invariably tends to a complete loss of self-respect and consequent degradation. It matters but little whether alms be medicine or food, the principle remains the same. The hungry must be fed; but we know that, instead of continuing to feed the hungry, and gradually destroying their power to help themselves, it is infinitely better to teach them how to help themselves and seek out and remove the cause that induced the miserable condition of helplessness. For exactly the same reason, would it not be better to teach the poor how to avoid getting sick, and by every means in our power remove the causes that induce disease among them, rather than to offer them the best care and attention without being sure that

they need help, and thus teaching them to become careless about avoiding sickness?

It would be more creditable to the citizens of New York if they could say that no such institution as a pauper hospital was needed within the limits of the city than to be able to say that two hundred established charitable institutions and organizations are maintained; and instead of so many millions being spent in caring for the sick, would it not be better if the same money, or perhaps only a small part of it, were spent in carrying out sanitary works, and teaching the people the laws of health?

Suppose, during the prevalence of a contagious epidemic, the authorities should content themselves with providing for those infected, and neglect to take the necessary steps to remove the cause of the disease by doing all that sanitary science indicated—they would soon be called to account for neglect of duty. It is a well-known fact that the great majority of the cases of disease treated in our hospitals are induced by the bad sanitary condition of the homes of the poor, and to the direct violation, *through ignorance*, of the plainest hygienic laws; yet what direct steps are taken to correct this constantly-acting cause of sickness? The Health Department of New York City is expected to do little else than prevent epidemics of contagious and infectious diseases. The meagre appropriation prevents them from doing much more.

This statement concerning the charities of New York City cannot be called a fair example of the condition of the hospitals and other charities in smaller places, but it shows very plainly and truthfully the prevailing faults in the administration of charities throughout the country; and if the condition and results of the charities of smaller places are not so bad, it is due to local circumstances, and not to a better understanding of the subject, nor to the adoption of a more enlightened system.

The circumstances are very much in favor of the smaller cities and towns. Leaving out the many well-known causes that tend to generate pauperism, and thus increase the relative number of paupers in a large city that do not exist in towns or small cities, the main reason that charity does not do so much harm in the latter is, that the circumstances and the character of every one are well known to the people, and this personal knowledge guides and directs the givers of charity; whereas in the large cities it is seldom that the giver of charity knows to whom he is giving, and *personal knowledge* rarely exists at all. The difference between the lives of the rich and the poor is so great that the rich cannot comprehend the real needs of the poor. Unless these *personal relations* exist between those that give and those that receive, no act of generosity deserves the name of that charity which "blesseth twice," for gratitude is not developed in those receiving help. They give nothing in return for what

they receive. Experience teaches that to do for an individual that which it is *possible* for him to do for himself will invariably tend to harm, unless he gives in return an equivalent, either by actual payment or in gratitude. And experience also teaches that human nature can only feel gratitude toward an individual.

Besides this tendency in hospitals as charitable institutions to increase pauperism, another serious objection to the use of public hospitals for the purpose of treating the sick beyond the extent absolutely demanded by necessity is, that every time an individual is removed from his home—let that home be ever so humble—and taken to a hospital, the family as an institution receives a blow.

Then, too, except to those already degraded, life in a pauper hospital, especially in the case of the young, is hardening to the feelings, while in many cases it subjects the moral to the influence of the immoral.

Another objection to hospitals is the bad sanitary condition of many of them, and unless this is improved, both as to the plan and the construction of the buildings, and the general and internal management, so as to give a smaller death-rate and fewer deaths from hospital-diseases than in the vast majority of hospitals now in use, it will be decidedly better, *on sanitary grounds alone*, to treat in their homes all the sick poor who have homes, even though they may be very bad and unhealthy places to live in. As to the expense of treating the poor at their homes, it certainly would not be greater than the expense of running the hospitals, if the interest-money is added which could be had from the immense sums that are sunk in the massive, many-storied hospital buildings, and the expensive city lots on which they stand.

But as poor-relief is now administered, and, no doubt, under the best system that could be devised, a certain number of hospitals for treating the sick poor will be necessary. When properly constructed and managed they are a great blessing to the poor, while, from the advantages they afford for the study and teaching of clinical medicine and nursing, they are of incalculable value to the whole community.

Since the establishment of the Training-School for Nurses in connection with St. Thomas's Hospital, by Miss Nightingale, in England, fifteen years ago, and, in this country, of the School for Nurses in connection with Bellevue Hospital, New York, three years ago, the great advantages of hospital-instruction are recognized for those who are studying nursing.

In the founding of hospitals, the question of their usefulness to medical education has not been given due consideration. As a rule, the idea of rendering immediate personal relief to the suffering poor is the first, and in many cases the only *acknowledged* object aimed at in establishing them.

The objections to civil hospitals as now stated may be said to be: 1. As institutions, they tend to weaken the family tie by separating the sick from their homes and their relatives, who are often too ready to relieve themselves of the burden of the sick and helpless of their family. Besides, when one or more of a family are removed those left at home are in an uncertain state of mind, and, in many instances, in an unprotected condition. 2. The inmates of pauper hospitals are liable to come in contact with bad influences: familiarity with suffering, unaccompanied by the *occupation* of relieving those who are suffering, ends in hardening the sensibility, especially in the young. 3. Like all public and general charities without the safeguard that personal knowledge affords, hospitals tend to foster idleness and helplessness, and their natural results, pauperism and crime. 4. When badly constructed or badly managed, they are liable to cause hospital-diseases among the inmates, and become centres of infection, thus defeating the very object they are intended to promote.

On the other hand, the arguments in favor of civil hospitals are: 1. They are a necessity under many circumstances for giving shelter to the sick and helpless, and are supposed to be the most economical method of providing for the sick poor. 2. They are of very great value as affording an opportunity for the comparative study of diseases, and for giving practical instruction in the science of medicine and the art of nursing to the greatest advantage, and thus, by helping directly a few individuals, indirectly rendering a service of incalculable value to the world. 3. During contagious epidemics they are a ready means of providing for those who are infected, and, by their isolation, preventing the spread of disease.

As means toward checking the undesirable multiplication of expensive institutions, toward preventing hospitals from breaking up or interfering with the family tie, and at the same time to keep them from engendering pauperism, we suggest: 1. Do all that can be done to enlighten the poor to help themselves, and to avoid the causes of disease. 2. Give indirect help by improving the condition of the homes of the poor, by strict laws in regard to the existence and building of all dwelling-houses, manufactories, schools, etc., etc., and in regard to the sale of food. 3. Limit hospital accommodations to those who have no homes, and to those who cannot be assisted at their homes.

It is doubtful if the state can give direct out-door help, even medical help, without doing more harm than good. It can only be done wisely by establishing a Bureau of Intelligence in connection with the police department, with offices at each police station, where the names and the numbers of the inmates in every house in the precinct or district would be known, and where, from personal knowledge, a record of all individuals receiving help—as to their circumstances, the amount of aid given, etc.—would be kept. As far as possible, all help rendered should be guided by this knowledge, and it should be obligatory on

all charitable institutions and associations to give information of all assistance rendered by them to individuals living in the district.

Through this Intelligence Bureau reliable personal knowledge of every applicant for hospital-relief could be obtained. We fully appreciate the great difficulty of organizing and uniting voluntary charities in this country, where there are so many different religious sects; but by establishing such a system as the above much could be done toward distributing help where it is really needed, and toward preventing indiscriminate charity, and in detecting impostors. To avoid the injurious moral effects of hospitals on the characters of the inmates, and to prevent such bad sanitary conditions in hospitals as are sure to result in retarding cures, and often in the generation of fatal hospital-diseases, it is necessary to have hospitals constructed and managed in accordance with the teachings of sanitary science.

## GEORGE HENRY LEWES.

THIS versatile thinker, known to science by his "Seaside Studies" and his "Physiology of Common Life"—works of much originality—as well as by his "History of Philosophy" and his "Problems of Life and Mind," in which he puts forth independent views on scientific methodology, was born in London, April 18, 1817. At an early age he was sent to the Continent of Europe to receive an education, but returned while still a lad, and was then placed under the tuition of Dr. Burney, at Greenwich.

The influence of his residence abroad, during the impressionable period of boyhood, is seen in a greater degree of vivacity than is usual among his countrymen. On leaving school young Lewes became a clerk in a mercantile house, but, as his tastes inclined him rather to a literary and scientific than a business career, he left the counting-house and took up the study of anatomy and physiology. His interest in these sciences appears to have sprung purely from a thirst for knowledge, as he did not purpose to become a physician. As early as 1836 he had in contemplation a treatise on the philosophy of mind, in which the doctrines of the Scotch metaphysicians—Reid, Stewart, and Brown—were to be physiologically interpreted, and, during the following year, he gave a course of lectures upon this subject. The investigations made at this time were destined to be suspended for a while, but later to be resumed and pushed forward into the most difficult provinces of philosophical inquiry. The years 1838 and 1839 he spent in Germany, devoting himself with characteristic assiduity to the study of literature and philosophy. Besides acquiring a mastery of the German language, he gained an intimate

acquaintance with German habits of thought. Even in his boyhood he was an indefatigable bookworm, and residence in Germany tended only to strengthen him in this habit, and to make him one of the most versatile writers and at the same time one of the most diligent students of the day. On his return to England, he for the first time felt, as he said, fully confident to enter on his career as a *littérateur*. He contributed to the columns of the daily press reviews and criticisms of books, and to the quarterly reviews and the leading literary magazines of England scientific and philosophical essays, biographical sketches, and the like. In 1849 he assumed the literary editorship of the *Leader* newspaper, which post he held till 1854. A London correspondent of an American journal, referring to this period of Lewes's life, says: "His criticisms, as indeed all his writings, were noted for piquancy, brilliancy, and boldness of thought. He had not only no objection to expressing his opinions; he was determined that the public should know them if they were capable of comprehending pungent and forcible English. He has never been a man with moral or mental reservations. As soon as he has a new thought, a new conviction, a new theory, he blurts it out. He was not long in making his mark, and from that time to the present, whatever has emanated from him has attracted attention and awakened interest." In 1865 he founded the *Fortnightly Review*, but was compelled by ill health to resign the editorship the following year; he was succeeded by John Morley.

His first elaborate work—a work which affords ample evidence both of his laborious industry and of his keen insight—was the "Biographical History of Philosophy, from Thales to Comte," first published in 1845. A fourth edition, corrected and partly rewritten, appeared in 1871 (2 vols.). An acute French critic says of this work of Mr. Lewes: "His history resembles rather that of Hegel than that of Ritter. His review of the labors of philosophers is rather occupied with that which they have thought than with their comparative importance. He judges rather than expounds; his history is fastidious and critical. It is the work of a clear, precise, and elegant mind, always that of a writer often witty, measured, possessing no taste for declamation, and making its interest profitable to the reader whom he forces to think. This is no ordinary history of philosophy; it is the work of an original mind which has a great deal to say, and yields voluntarily to the pleasure of saying it, a mind which handles texts like a thinker, not like a scholar. Assuredly we must not search Mr. Lewes's pages for enlightenment upon obscure points and upon controverted passages; but in this long journey from Thales to Comte the author has taken amazing pains, and has put forth enough teaching to content some, to leave others discontented, and to make every one reflect" (Ribot, "English Psychology"). In the preface to this history Mr. Lewes offers the following definition of the

limits of theology, philosophy, and science: "Theology, philosophy, and science," he writes, "constitute our spiritual triumvirate. . . . Its [theology's] main province is the province of feeling; its office is *the systematization of our religious conceptions.* The office of science is distinct. It may be defined as *the systematization of the order of phenomena considered as phenomena.* The office of philosophy is again distinct from these. It is *the systematization of the conceptions furnished by theology and science—ἐπιστήμη ἐπιστημῶν* (the science of sciences). This "History of Philosophy" was commenced by its author with the definite purpose of showing the radical weakness of all metaphysics. "The history of philosophy," he writes, "presents the spectacle of thousands of intellects—some of the greatest that have made our race illustrious—steadily concentrated on problems believed to be of vital importance, yet producing no other result than a conviction of the extreme facility of error. The only conquest has been *critical*, i. e., physiological." His opinion of the value of scientific methods in philosophical inquiry is expressed in the following passage: "'There are many who deplore the encroachment of science, fondly imagining that metaphysical philosophy would respond better to the higher wants of man. This regret is partly unreasoning sentiment, partly ignorance of the limitations of human faculty. Even among those who admit that ontology is an impossible attempt, there are many who think it should be persevered in, because of the 'lofty views' it is supposed to open to us. This is as if a man, desirous of going to America, should insist on walking there, because journeys on foot are more poetical than journeys by steam. He dies without reaching America, but to the last gasp he maintains that he has discovered the route on which others may reach it." In 1853 Mr. Lewes contributed to Bohn's "Scientific Library" a volume entitled "Comte's Philosophy of the Sciences."

Five years later (1858) appeared his "Seaside Studies at Ilfracombe." For the meeting of the British Association, the same year, he prepared a paper on "The Spinal Cord as a Centre of Sensation and Volition;" in 1859 he published three papers on "The Nervous System," in which he combated the received doctrines. These papers gave rise to a warm discussion among British physiologists, and even attracted much attention on the Continent of Europe. The "Physiology of Common Life" appeared in 1860, and in the following year was published "Studies in Animal Life." The object of these researches into the nervous system of animals and man was, as he informs us in the preface of his latest work, to obtain the clew through the labyrinth of mental phenomena. Misled by the plausible supposition that the complex phenomena in man might be better interpreted by approaching them through the simpler phenomena in animals, he began to collect materials for a work on animal psychology. But he was not then aware that, rightly to understand the mental condition of animals,

we must first gain a clear vision of the fundamental processes in man; for it is only through our knowledge of the processes in ourselves that we can interpret the manifestations of similar processes in them. Here again we are hampered by the anthropomorphic tendency which leads us to assign exclusively human motives to animal actions. In 1864 he published "Aristotle: a Chapter from the History of Science," with analyses of the Stagirite's scientific works. This work was republished in 1873. Since that time he has published, in two volumes, the first series of "Problems of Life and Mind," which was noticed in the MONTHLY, No. 42. The other published works of Mr. Lewes are: "Ranthorpe—a Tale" (1847); "The Spanish Drama," and "Rose, Blanche, and Violet," a novel (1848); "The Noble Heart," a tragedy, and a "Life of Robespierre" (1850); "Life and Works of Goethe" (1855), indisputably the best work on the subject. Besides these separate volumes he is, as has been already stated, the author of a multitude of essays, reviews, criticisms, etc., in the periodical press.

Personally, Mr. Lewes is described as rather small in stature. His face gives no very clear indication of the mental power he unquestionably possesses. His health has always been infirm, and he looks older than he is. From his portrait, one might imagine Lewes to be a man accustomed to life out-of-doors, though he has always been a close student and a resident of London, or other large capitals. His manner differs markedly from that of the generality of Englishmen. "In his own set," writes the newspaper correspondent already quoted, "he abounds in geniality and *bonhomie*. He does not remind you of an Englishman; he has none of the hesitation or drawl so typical of his nation, but talks with marked ease and fluency and radiance. He is fond of epigram and paradox, and, being a close observer, his narration of men and things is extremely entertaining. He has the reputation of being one of the most brilliant conversationalists in London, though, like most clever talkers, he is prone to monopoly and monologue." As an author he is slow and painstaking, and the longer he lives the more careful and conscientious does he become in this respect. He does not believe that thoughtful and growing men acquire facility with years, and says that when he was forty he would do four or five pages in the time now required for one. Some years ago he married the eminent novelist, Marian Evans, known to fame as George Eliot. They live in one of the suburbs of London, and their home is represented as being one of the happiest, the likeness of their pursuits and ambitions being an additional bond of unity.

# CORRESPONDENCE.

## ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

*To the Editor of the Popular Science Monthly.*

AT the risk of appearing ungracious, and possibly fastidious, I beg leave to invite attention to some inaccuracies in a brief notice of the Academy of Natural Sciences of Philadelphia, published in THE POPULAR SCIENCE MONTHLY for August, 1876. The statements are erroneous; and, taken as a whole, the article does not fairly present the Academy to the public. The enthusiasm of my learned friend Prof. Cope has possibly led the writer of the article into misconception.

THE POPULAR SCIENCE MONTHLY says, in substance, that Prof. E. D. Cope availed himself of the occasion of the Academy's taking possession of its new building "to suggest in the *Penn Monthly* some needed changes and improvements" in the organization of the society.

Prof. Cope, in his article on "The Academy of Natural Sciences" in the *Penn Monthly*, mentions that the Academy while changing its location revised its organization, "adding some functions which shall" relate it to the public more nearly than heretofore; that "its founder," meaning, of course, its seven founders, designed that the objects of the society should be promotion of original research, of instruction, and of the diffusion of knowledge.

Prof. Cope, Corresponding Secretary of the society, and at the period referred to one of a committee instructed to revise the by-laws with a view to improvement, did suddenly conceive and hastily deliver to the public press, contrary to the usual practice in such cases, an article referring to matters which were under consideration of the committee at the time, possibly in expectation that a small minority on some points of peculiar interest might be made a majority through the influence of his eloquence.

THE POPULAR SCIENCE MONTHLY says that the Academy has "a moderate fund for promoting" the diffusion of knowledge, and regularly publishes "Transactions."

The Academy has a very modest "publication-fund," but it has never put forth anything under the title of "Transactions." It publishes the *Journal of the Academy of Natural Sciences of Philadelphia* (quarto), and the *Proceedings of the Academy of Natural Sciences of Philadelphia* (octavo), the first now including 6,592 pages and 565 plates, and the second, 10,692 pages and 136 plates, which together constitute the Academy's records of original research.

"Original research is not materially encouraged by the Academy."—THE POPULAR SCIENCE MONTHLY.

Original research is considerably encouraged by publishing the reports of investigators, and by giving them freely the use of a scientific library of 25,000 volumes, and of extensive collections of natural objects while engaged in their work. If it is meant that the Academy does not encourage original research because it does not feed, lodge, and clothe investigators, or pretend to compensate them in any manner for scientific work, the charge must be admitted. It may truly plead, however, in extenuation of the illiberal policy of which it is accused, that its resources have never exceeded its current expenditures for fuel, light, postage, freight, etc., etc. The Academy is accused, indirectly, with doing less to encourage original research than might be done with its means: "for," says THE POPULAR SCIENCE MONTHLY, "in one instance funds, supposed to be devoted to research, were hoarded, and afterward turned over to the building-fund."

The Academy never had funds which were in fact or "supposed to be devoted to research." The assertion to the contrary is not true. A section of the Academy had a surplus accumulation in its publication-fund, and generously contributed a part of it to aid the Academy to finish its building. The members of that section are as earnest in the promotion of the interests of science

and of the Academy, and as intelligent in the application of their means, as the gentleman who makes their gift the basis of an accusation of dereliction of duty against the Academy.

THE POPULAR SCIENCE MONTHLY says, "Less than five hundred dollars per annum is devoted to 'instruction.'"

For this purpose the Academy expends $480, the entire proceeds of a fund bequeathed to it for this object. Is it reasonably honest to make it a fault that it does not spend more for a specific purpose than it has to spend?

Again, "The chief fault found by Prof. Cope in the organization of the Academy is that, while it secures good financial management, it minimizes the scientific features of the body." And, as if to sustain the assertion that the organization minimizes the scientific features of the body, we are gravely assured, in a somewhat contemptuous manner, in the words of Prof. Cope, that "its officers are the usual president, vice-president, secretary, etc., constituting a management as appropriate to an historical society, library company, or, I might add, church vestry, as to an academy of natural sciences. It has no position designed for its distinctive and essential feature, its scientific experts."

Since its foundation the organization of the society has been frequently and carefully revised. In 1858 provision for the formation of departments, which were called sections in 1868, was made. About six years ago a council was added to it, and in May last the council was enlarged, and authorized to elect thirteen professors, but no source of compensation or rate of compensation has been provided for them. Positions for its scientific experts have been thus provided. In this revision of the organization it was considered to be not expedient at this time to dispense with president, vice-presidents, secretaries, treasurer, etc., although it is freely admitted that these officers are as appropriate to a church vestry as to an academy of natural sciences.

It is made the duty of each professor to preserve, classify, and increase the collections in his department, and report annually their condition and needs to the council, to give special or objective instruction to the beneficiaries of the scholarships in the Academy, and to deliver courses of lectures, under such regulations as the council may establish.

If any properly-qualified gentleman is willing to assume the duties of a professorship without pecuniary compensation, his services will be cheerfully accepted, and he will be encouraged to pursue original investigations as far as can be done without money. It is conjectured, however, that competition for these chairs will not be very active until they are adequately endowed.

The old building was universally admitted to be crowded to excess, and that more space was needed for the collections as well as for the library. Prof. Cope speaks of the collections, and considers them, with one or two exceptions, as extremely meagre, and tells us that a great museum of the future, to be complete, should contain 10,000,000 species of animals, represented by "several specimens of each," aggregating from 30,000,000 to 50,000,000 specimens, adding in the sequel that all the money spent on the new building would have been "as well spent in endowing chairs in the old locality."

In spite of the authority of Prof. Cope's opinion thus implied, that the old building was large enough, it is now found that a half-million of specimens cannot be satisfactorily displayed in the new edifice, though it is twice as capacious as the old one. There is already urgent demand for more space, and this is so evident that contributions to the building-fund have been recently made with a view to an immediate completion of the edifice conformably to the approved plans of the architect. No one thing which can be done now is likely to promote the prosperity of the Academy in the future to a greater degree than to finish the building without loss of time. Efforts to augment the collections will not be very earnest, nor successful in result, until there be accommodation for additions which may be made to them. Original investigation will be more active in the Academy when it can offer a well-appointed laboratory for the use of workers; and an apartment suitably furnished to accommodate an audience, and enable the professors to illustrate their teachings, is prerequisite to the delivery of

systematic courses of popular or elementary lectures on natural science in the Academy. The completion of the building will facilitate and strengthen all the functions of the society in all its departments, and lay the foundation of a workshop in which experts and students may pursue investigations advantageously to science and themselves.

The progress of the Academy has been always deliberate and unobtrusive. It will so continue until accelerated by enlarged resources.

To the full extent of its means the Academy encourages original research, gives instruction to those who seek it, and promotes the diffusion of knowledge. Its doors are never closed against a student or votary of science; every one is cordially welcome, and given such assistance and facilities as the society has, which are all charitable gifts, benevolently aggregated and preserved here for the benefit of the intellectually hungry. It may be safely conjectured that its usefulness will increase, *pari passu*, with the augmentation of its pecuniary resources, unless Utopian projects of scientific grandeur and exclusiveness be injected into its policy.

Observance of that wise and holy precept, *suum cuique*—to Cæsar the things which are Cæsar's—relatively both to substantial things and mental products, would save us all a world of trouble and vexation. Commending the consideration of this precept to my readers most cordially, I am,

Very respectfully,

W. S. W. Ruschenberger.

Philadelphia, *August* 1, 1876.

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## LIMITS OF THE WESTERN GRASSHOPPERS' RAVAGES.

*To the Editor of the Popular Science Monthly.*

In The Popular Science Monthly for July I find the statement quoted from Prof. Riley that the southern limit of the locust ravages is the 44th parallel of latitude, and the eastern limit the 103d meridian. The latitude of this place is 39° 52′ nearly. As I write, the locusts are flying so thickly as to give sunlight the yellow tinge of dense smoke. Last night, in a single hour, whole fields of barley were eaten to the ground, and the fields swept cleaner than the harvester could have done the work. These ravages to-day extend one hundred and twenty-five miles south of this place, or to latitude 37°, and how much farther the news has not reached me. Their appearance here is neither unexpected nor exceptional. During the three preceding years agricultural products throughout Colorado were almost entirely destroyed, and thousands of farms were financially ruined. They have visited us to a greater or less extent annually for the last twelve years, and their ravages have often extended as far east as Lawrence, Kansas, or two hundred miles east of the line prescribed in the article referred to. Our altitude is 8,300 feet above the ocean, but this is not their limit. A few days ago I was on a mountain-summit, 14,000 feet in height, and there they were flying to the westward, high overhead, in immense clouds. Many plans are resorted to for their destruction. Kerosene dripping slowly upon the water in irrigating ditches is very effective. Traveling machines, filled with fire, passing over the ground like mowers, destroy millions; but when they come in clouds, as to-day, I know of no defense at all adequate.

I have driven them a hundred times to-day from the little twenty-foot green spot in front of my house, and yet there are as many there as if I had done nothing. Fortunately they are fastidious, and often will not eat grass, potatoes, or oats.

There is one remedy which I believe would be effective, and that is the preservation of prairie-grouse and other insectivorous birds. The number of locusts eaten by prairie chickens and quails is perfectly marvelous. For the destruction of hawks and eagles there should be a reward offered by the State. This would preserve many of the birds; and heavy fines imposed for the destruction of birds, at any time of the year, would work the rest.

As long as Colorado, Kansas, and Nebraska, permit the unlimited slaughter of these, their best friends and preservers, they deserve to suffer from the devastation of the locusts, or grasshoppers, as we call them. Respectfully yours,

D. C. Collier.

Central City, Colorado, *August* 10, 1876.

## ACCIDENTAL VARIATION.

*To the Editor of the Popular Science Monthly.*

THE following figures and description show a somewhat interesting case of accidental variation:

The antlers are those of a common deer (*Cervus Virginianus*). The buck from which they were taken was about five years old, and was shot by a gentleman of long and varied experience as a hunter; he thinks them quite exceptional in shape.

FIG. 1.

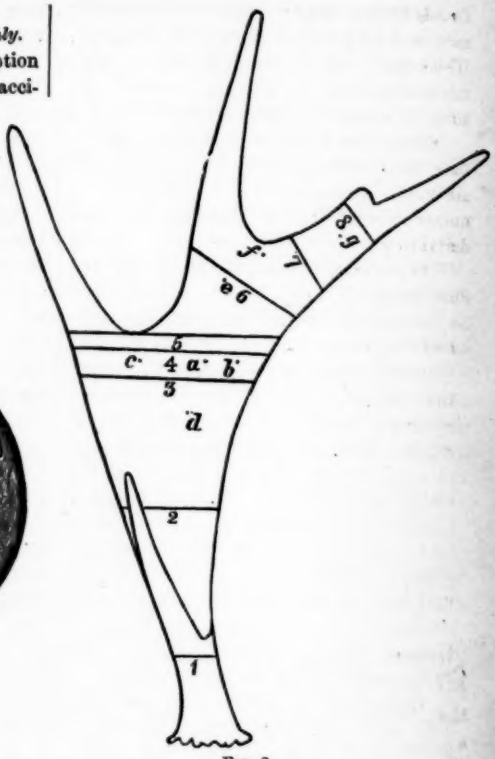


FIG. 2.

In their dimensions and their great width, as compared with thickness, they show a strong resemblance to the palmated antlers of the caribou, or an approach to the antlers of the elk.

Fig. 1 shows the position and curvature of the antlers. As indicated, they differ somewhat in outline, and the left one is shorter and broader than the right.

Fig. 2 is a reduced sketch obtained by tracing the outlines of the left antler on a large sheet of paper, and then corrected by careful measurements with calipers.

The measurements are:

| | |
|---|---|
| Width from tip to tip | 15¾ inches. |
| Length of exterior curvature from root to tip | 18¼ " |
| Direct height | 14¼ " |
| Width at 1 | 1⅝ " |
| " 2 | 2¼ " |
| " 3 | 4⅛ " |
| " 4 | 4⅝ " |
| " 5 | 5⅛ " |
| " 6 | 3 " |
| " 7 | 1⅛ " |
| " 8 | 1⅛ " |
| Thickness at *a* | ⅜ inch. |
| " *b* | ½ " |
| " *c* | ⅝ " |
| " *d* | ⅝ " |
| " *e* | ½ " |
| " *f* | ⅜ " |
| " *g* | ½ " |
| Girth at root of antler | 5⅜ inches. |
| " 2 | 5¼ " |
| " 4 | 10½ " |
| " 7 | 4⅛ " |
| " 8 | 4½ " |

E. R. LELAND.

EAUCLAIRE, WIS., *June* 19, 1876.

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## WHO ERECTED STONEHENGE?

*To the Editor of the Popular Science Monthly.*

WHEN a boy, the writer walked many miles to visit Stonehenge. He was utterly alone with these hoary ruins on that treeless plain, and retains, after a third of a century, a vivid reminiscence of the scene and its suggestions.

The attribution of these remains to the

Druids always seemed to him quite as absurd as if a discoverer of the mounds of the Mississippi Valley should credit them to the medicine-men of the Indian tribes who alone were found in their vicinity.

Neither Cæsar nor any other ancient author found in the Keltic population of Britain any indication of either the skill or the numerical force commensurate for such undertakings.

The vast slabs composing the circles of Stonehenge are now, it is true, as they were no doubt in Bede's time, shapeless, *with one notable exception.*

Some of the slabs which have more recently, say within a thousand years, lost their lintels exhibit the unique feature of a duplex tenon, while the lintels show the corresponding mortises. Now this dovetailing, so to speak, of masonry, shows architectural skill and genius of a high order — immeasurably ahead of anything the Kelts were capable of; nay, more, in advance of even modern art in this department. Further, the material of Stonehenge must have been transported many scores of miles. A people so advanced as to mortise their masonry would scarcely have left the exterior surfaces unchiseled.

The tenons were protected in their inclosing mortises, while the storms of, it may be, two hundred centuries rasped off all vestige of the pristine beauty of their exteriors.

G. H. KNIGHT.

CINCINNATI, *August* 23, 1876.

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# EDITOR'S TABLE.

### *FURTHER CONCERNING THE "SOUND" CONTROVERSY.*

SOME months ago, as our readers will remember, there appeared in the *Nation*, by an anonymous writer, a scandalous attack upon Prof. Tyndall. He was accused of treating Prof. Henry dishonorably; and the accusation was so garnished with insulting insinuations as to convey the impression that Prof. Tyndall is not above ignoring and suppressing other people's valuable work which he desires to profit by himself. It was a matter of painful surprise to many that any man could be found, in this country, to make such charges on no better grounds than were alleged against an eminent and absent gentleman of hitherto unsullied character; or that any respectable American newspaper would lend itself to their publication. For this was one of those palpable cases in which some decisive weight should have been allowed to character at the outset. While on the one hand charges were raised of which the proof was not furnished, and a specious case was made out by unscrupulous ingenuity which was calculated to mystify and prejudice ordinary readers, on the other hand the imputations against Prof. Tyndall were specially contradicted and discredited by the quality of his whole life. He was eminently not the man to do the things alleged. The intimate friend and successor of Faraday, and for the last twenty-five years Professor of Natural Philosophy in the Royal Institution of Great Britain, his life and works have been in an eminent degree public and conspicuous. An assiduous investigator in various branches of physics, he has published freely in the Transactions of the Royal Society; a clear and vigorous writer, appreciating the necessity of improving popular scientific literature, he has also written copiously for the public, on many of the most recent and exciting questions of science. Perhaps there is not another eminent man of science, in any country, whose intellectual life has been more open to scrutiny than that of Prof. Tyndall. Yet with this prolonged and intense exposure of his mental work to a world sufficiently censorious — and though often in sharp conflict with other investigators — his reputation as a man of the strictest honor in relation to all the rights and claims of his

scientific co-laborers has been unquestioned.

Moreover, those best acquainted with Prof. Tyndall know that his solicitude in doing justice to his scientific brethren, as evinced in difficult circumstances, is so earnest as to be almost morbid. No man is freer from petty jealousies, or the narrowing influence of national bias, than he. Attaching a serious meaning to the common sentiment that "science is of no country," he has stemmed the violent currents of local feeling in his own, and aimed to be just and generous to foreigners when their claims have been depreciated by British scientists. This is perfectly understood by all who are familiar with recent scientific controversy. His championship of the German Mayer, the Savoyard Rendu, and the American Agassiz, when their rights as discoverers were denied by his own countrymen, showed the breadth of his sympathies and the strength of his sense of justice. Nor is it improper here to add that he came to this country to help on the work of science, moved by no low or sordid considerations. He resisted social solicitations in a way that was not a little misinterpreted, that he might do the work he had undertaken in the best manner; and contributed all that he got from half a year's hard labor to assist in the scientific education of worthy young men of this country for whose special aid there had been, hitherto, no provision.

We submit that these considerations should have been sufficient to protect Prof. Tyndall from the gross assault in the *Nation*, which could not be replied to until a sensation-seeking press had scattered the calumnious charges from one end of the country to the other. Something, we say again, was due to character, that should have prevented the diffusion of such aspersions until they had been thoroughly looked into, and the party most concerned had been consulted. We appeal to every candid reader, if it would not have been a fairer proceeding for the editor to have sent the article to Prof. Tyndall, if he thought it worth attention, and to have asked him what it meant, that the defense might have accompanied the attack, had he still thought the matter proper for publication.

The case has now assumed a different aspect. The anonymous writer in the *Nation* has recently rehashed and amplified his statement, put his name to it, and published it in the *New York Tribune*. It is noteworthy that, while the writer announces himself to have been an assistant of Prof. Henry, he recognizes the necessity of disavowing all complicity on the part of that gentleman in these assaults upon Tyndall. It would have been well if this had been thought of a little earlier; and there is no reason for the disclaimer now that should not have impelled Prof. Henry to protect himself from misapprehension, by following the publication of the article in the *Nation* by a prompt statement of the fact that he had nothing whatever to do with it.

With the larger portion of the communication to the *Tribune* we have no concern, as its four closely-printed columns are chiefly occupied in trumping up new and petty imputations against Prof. Tyndall that are wholly unworthy of notice. Borrowing a hint from the tactics of our political canvass, the writer seems to think that the way to substantiate one charge is to pile up more. But the case, as now even more fully presented, has not a leg to stand upon. In fact, the writer has put an end to it himself by attempting to give his proofs. We have said that the article in the *Nation* made charges without giving the evidence; that evidence is now forthcoming, and, as we shall see, instead of sustaining, refutes the charges and explodes the case.

Prof. Tyndall had said in his book on "Sound" that Dr. Derham's paper, published in 1708, and which contains

the views which have generally prevailed upon the subject since, "*marks the latest systematic inquiry into the causes which affect the intensity of sound in the atmosphere*," up to the time of his own investigations in 1873. This period he characterizes as a *blank*. He does not deny that facts of importance had been observed in the interval, or that partial inquiries had been made leading to valuable conclusions; but the "blank" is declared to consist in the absence of any "systematic inquiry into causes," such, of course, as generally lead, when ably conducted, to the reconciliation of conflicting views, and the establishment of principles which are entitled to take their place in the body of scientific knowledge. To this the writer in the *Nation* replied that Prof. Henry had made such systematic inquiries, and that Prof. Tyndall knew it from a paper which he heard Prof. Henry read in Washington. The evidence of the charges against Prof. Tyndall of "ignoring" or "suppressing" the work of Henry, or of taking advantage of it in his own subsequent investigation, is, therefore, to be found in this paper, if anywhere. The writer of the article in the *Nation* did not adduce the article, although his whole case rested upon it. Challenged for his evidence, he now brings it forward in the *Tribune*, makes extracts from it, and states what else it contained; and we now give his whole reference to it, italics and all:

"Prof. Henry prefaced his paper on that occasion with the following reference to Dr. Tyndall's presence: 'The communication which I propose to make this evening is brought forward at this time especially on account of the presence of Dr. Tyndall, he being connected with the lighthouse system of Great Britain, while the facts I have to state are connected with the lighthouse service of the United States, and must therefore be of interest to our distinguished visitor. The facts I have to present form part of a general report to be published by the United States Lighthouse Board.'

"After briefly treating on the prevalence of fogs upon the American coast, Prof. Henry proceeded to consider their scientific relations to fog-signaling, and remarked as follows:

"'In studying this subject it becomes a question of importance to ascertain whether waves of sound, like those of light, are absorbed or stifled by fog; on this point, however, observers disagree. At first sight, from the very striking analogy which exists in many respects between light and sound, the opinion has largely prevailed that sound is impeded by fog. But those who have not been influenced by this analogy *have in some instances adopted the opposite opinion that sound is better heard during a fog than in clear weather.* To settle this question definitely the Lighthouse Board have directed that at two lighthouses on the route from Boston to St. Johns the fog-signals shall be sounded every day on which the steamboats from these ports pass the station, both in clear and foggy weather, the pilots on board these vessels having, for a small gratuity, engaged to note the actual distance of the boat when the sound is first heard on approaching the signal, and is last heard on receding from it. The boats above mentioned estimate their distance with considerable precision by the number of revolutions of the paddle-wheel, as recorded by the indicator of the engine, and it is hoped by this means to definitely decide the point in question. We think it highly probable that fog does somewhat diminish the penetrating power of sound, or, in other words, produce an effect analogous to the propagation of light. But when we consider the extreme minuteness of the particles of water constituting the fog, as compared with the magnitude of the waves of sound, *the analogy does not hold except in so small a degree as to be of no practical importance, or, in other words, the existence of fog is a true, but, we think, an insufficient, cause of diminution of sound, which view is borne out by the great distance at which our signals are heard during a dense fog.* Another cause, which without doubt is a true one, of the diminution of the penetrating power of sound is the varying density of the atmosphere, from heat and moisture, in long distances. The effect of this, however, would apparently be to slightly distort the wave of sound rather than to obliterate it. *However this may be, we think, from all the observations we have made, the effect is small in comparison with another cause, viz., that of the influence of* WIND. During a residence of several weeks at the sea-shore, the sound of the breakers at a distance of about a mile in no

case appeared to be coincident with the variations of an aneroid barometer or a thermometer, but in every instance it was affected by the direction of the wind. The variation in the distinctness of the sound of a distant instrument as depending on the direction of the wind is so marked *that we are warranted in considering it the principal cause of the inefficiency in certain cases of the most powerful fog-signals.*'

"In the remainder of his paper, as read in the presence of Prof. Tyndall, the chairman of the Lighthouse Board applied the hypothesis of Prof. Stokes to an explanation of certain abnormal phenomena of sound which had been observed during the course of his systematic inquiries with regard to the causes which affect the intensity of sound."

The reader now has the whole case before him. This is the substance of what Prof. Tyndall listened to in Washington, and for not recognizing which, to the credit of American science, in his book on sound, he has been the subject of a bitter and persistent newspaper attack. Prof. Tyndall says that the reading of the document left him in mental perplexity, and we are certainly not surprised at his state of mind. The subject, it is to be remembered, was not new to him. He had been for years engaged in the scientific service of the English Lighthouse Department; he had been an explorer in the field of acoustics, and was familiar with the history of the subject. He knew that it was involved in obscurity, that observations disagreed, and that there was much theoretical conflict about it. Nothing seemed established, and he states that Prof. Henry's paper left him still in an intellectual fog in regard to the whole question. The reader will see that the statement is pervaded by doubt. Conflicting opinions are given, and the prominent question was yet to be decided by the aid of Boston pilots. Finally, a conjecture, thrown out by an English physicist, is invoked for the explanation of anomalous effects observed. Clearly it was a case for further and formidable work which required to be met by a comprehensive, systematic, and thorough-going research. Prof. Henry's paper settled nothing. That it was without value as a contribution to science, we by no means assert; but every one can see that it was not the product of a full, methodical, and exhaustive inquiry, such as the subject urgently demanded and had not yet received from any source. The observations of Humboldt, early in the century, on the passage of sound, were important, as Prof. Tyndall himself attests, but to characterize them as a "systematic inquiry into the causes which affect the intensity of sound in the atmosphere" is simply absurd. Humboldt confined himself to one branch of the investigation, and whole tracts of it he did not touch.

Prof. Tyndall was, therefore, abundantly justified in assuming that the blank of 167 years had not been filled up; and, being deeply interested in the subject, and having command of the means for an elaborate course of researches upon it, he determined to enter fully into the inquiry, with the hope of dispelling some of the uncertainty which clouded it.

He took up the question from a purely scientific point of view, not to improve the art of fog-signaling or arrive at any immediate practical results valuable to the navigator, but simply to test theories, explain phenomena, harmonize discrepancies, and advance acoustical science. He attacked the problem of the "causes" which affect the intensity of sound in the air with a single-mindedness, a rigor of method, and a completeness of resources, that had never before been employed upon it. His researches went on in a double series, on the coast and in the laboratory. Using the facilities furnished by the Government at home, and sending abroad for the best that could be supplied, he carried on his observations and experiments on a large scale from the South Foreland Station, scrutinizing

and testing the various views and suggestions that had been proposed, and arriving at new and important conclusions in regard to the causes of which he was in search. He then subjected these conclusions to elaborate experimental verification by newly-devised apparatus, and original researches in the Royal Institution, with the attainment of results which will probably take their permanent place among the principles of acoustical science. At any rate, the subject, with its accumulated difficulties, had never before received so efficient a sifting and overhauling; and it was this that Prof. Tyndall meant, and had a right to mean, by the phrase "systematic inquiry into causes," in which he characterized his work. The writer in the *Tribune* can entertain his own views as to what that phrase signifies in dealing with the phenomena of Nature, but Prof. Tyndall will be perfectly easy in leaving this matter to the judgment of scientific men.

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### *THE AMERICAN ASSOCIATION AT BUFFALO.*

THE meeting of the American Association for the Advancement of Science, which began August 23d and lasted a week, has been unusually successful. There was a strong attendance of members, and a greater number than at any previous session of foreigners distinguished in science. A large number of papers were contributed to the proceedings, several of them important and of marked originality. Prof. Rogers presided with characteristic dignity and grace, and the retiring president, Prof. Hilgard, gave an instructive address, devoted mainly to his own department of study, and giving a sketch of the progress of the scientific measurements and mapping of the earth.

And the meeting was a success socially as well as scientifically. The citizens of Buffalo extended their hospitality in the most liberal manner to members and visitors, and the local committee made efficient arrangements for the accommodation of all who desired it. There were the usual receptions, which were largely attended and much enjoyed. It is given to but few places to favor their guests with so pleasant a treat as a day at Niagara Falls.

The Buffalo people owe their best thanks to Mr. Secretary Grote, of their young Academy of Sciences, for his efficient agency in securing the meeting to their town on this memorable year, as Philadelphia was a powerful rival for the honor. It is through this little scientific society, which has had to struggle on with insufficient means, sustained by a few who were heartily interested, that the citizens of Buffalo have been roused to invite the convention and to extend to its members so cordial a welcome. We hope that the stimulus thus given to the public interest in scientific subjects will bear permanent fruit and result in establishing the Buffalo Academy upon a liberal and permanent foundation.

But, while Buffalo has done its duty admirably toward the Association, has the Association in turn done its duty to Buffalo? Is duty in such a case a wholly one-sided thing, or are men of science such lions that they pay off their hosts by their bare presence? We do not suppose that the hospitable Buffalonians had an eye to what was to be got back from their guests, but obligations were nevertheless incurred, and it is proper to inquire how they were met. The citizens of that town, having no experience, did as those of other towns always do on these occasions—promised themselves great pleasure in attending the sessions of the Association. They drifted in freely at the opening meetings, but, after being peppered for an hour with unintelligible terms, they generally withdrew in a quiet way, and with their ardor cooled for discussions that could but little interest people at large.

The obvious logic of the case must have been that, although this scientific convocation was occupied with its own avowed and proper business, yet so far as ordinary outside folks were concerned it was something of a "sell." Now, we venture to think that this is all wrong, and if the American Association for the Advancement of Science were more liberally managed, it would recognize an important duty that it owes the public in each city where it is invited to hold its sessions. Granting that its strict and special aim is the advancement of science by original contributions to its various branches, and that its proper work is necessarily technical, and to be carried on in the little meetings of the scientists themselves, it is nevertheless true that there is a side of science in which the public is deeply concerned, and such a body as this, which goes annually from city to city, and has a great power of influencing the people for good, has no right to ignore its responsibility. The people are constantly appealed to by scientific men to give their money, while they live and when they die, for carrying on scientific investigations that are necessarily and largely expensive. Scientific men, in fact, must depend upon the public, and be supported by it. They, therefore, incur obligations, and cannot escape them. If science is a beneficent agency for all, if scientific truth requires to be diffused that every grade of society may reap its benefits in some form, then men of science, who have the knowledge and the capacity to present it in familiar and popular forms, are bound to do what they can according to their gifts and opportunities to promote these objects. The American Scientific Association, every time it enters a new city to hold its meeting, should contribute something useful and valuable for the instruction and enlightenment of all classes. It is a peculiar opportunity which should not be thrown away, and there are always men present competent to do the work, and who would cheerfully enter into it if it were a part of the regular arrangements of the Association. The British Association has done its duty in this respect for years. It has provided for the delivery of outside lectures, popular lectures, lectures to working-men given to the people in large halls, by the best talent of the body, and such gentlemen as Carpenter, Tyndall, Spottiswoode, Frankland, Huxley, Roscoe, and others, have not hesitated to do their share of the work when called upon. Notwithstanding all our talk of progress and the education of the people, the old monarchical and aristocratic country is far ahead of us in these matters. The American Association seems strangely indifferent to this aspect of its usefulness. It shirks its palpable duty in giving impulse and direction to general scientific education, and this omission to provide instructive lectures for the people at its yearly meetings seems further to show that it cares nothing about scientific teaching in any shape for public purposes.

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### *THE AIR IN COURTS OF JUSTICE.*

JUDGE MONELL is dead; and we are informed he died of the foul air of the court-rooms in which he had officiated. Why should court-rooms poison those who frequent them, like Calcutta Black-Holes? We have not been often in such places, but we were never in a court-room yet that we did not think a fit subject for the action of the grand-jury as an indictable nuisance from its bad ventilation. Lawyers seem to be a good deal behind the age in the appreciation of pure air. When the chemists have gone to different places after samples of foul air, they generally report the worst from court-rooms. The way these are constituted for breathing-purposes is an excellent example of the way things are generally

done by Government. Court-houses are built by the State, and usually with a large regardlessness of expense. But they are the work of architects, and are constructed more for external ornament than internal use. They please the eye of the passer with their stateliness, and asphyxiate the judges within. Money is profusely spent, and the building unfit to be used. And so with all places where politicians congregate, and Government provides the edifice. There came a wail from Washington during the last session that our Congressmen were being stifled by the bad ventilation of the House of Representatives. Millions upon millions have been put into the structure, and the whole world is called upon to come and admire its grand proportions and imposing effect, while the legislators within are being suffocated. The best Government in the world strangles its lawgivers with mephitic gases instead of allowing them to breathe pure air. But, before sickness and death can come by poisonous inhalations, there are stages of atmospheric deterioration in which the mind only is affected. The brain, the immediate instrument of thought and feeling, receives and requires the largest proportion of pure arterialized blood of any portion of the body. This is necessary to its functions, so that we cannot think, remember, compare, reason, and judge well, except in pure air, which maintains the mind's organ in its highest vigor and keenest action. Long before judges die and Congressmen take sick they must pass through this stage of cerebral depression, blunting of the sensibilities, and perversion and deadening of the mental operations. How much of the stupidity of legislation and the miscarriage of its judicial application may be due to the muddled brains of lawmakers and judges from breathing the pestilential air of legislative halls and courts of justice, it may be impossible to tell, but the inquiry is suggestive. It is also pertinent to ask, What sort of education can these parties have had, to submit to these conditions, even to the destruction of health and life?

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### *THE "CONFLICT" AND THE "WARFARE."*

THE anxiety with which historic works on the relations of science and religion are now sought is a fact of special interest, and we think it a salutary symptom of the state of the public mind. Science has opened the question, and the world is taking hold of it in earnest. "The History of the Conflict between Religion and Science," by Dr. Draper, while being most vigorously pooh-poohed by those who did not like it, has steadily made its way, through translation, into nearly all the Continental countries, and is at last so loudly called for even in benighted Spain that two editions of it by rival publishers are reported as having appeared in Madrid. What possible or conceivable hope is there that religion and science in that country can ever be brought into genuine amity until there is first an intelligent recognition of what have been their past relations? President White's brief but telling sketch of "The Warfare of Science," though first widely circulated in the pages of this magazine, had to be reprinted, and in a few weeks has reached a third edition in this country, while it has been republished in England, and will undoubtedly be translated, as it deserves to be, into the chief European tongues. The merit of these works, and the secret of their success, are not more due to the ability with which they have been prepared, or the manly and fearless tone with which they discuss questions of the gravest importance, than to their opportune appearance and adaptation to the wants of a rapidly-widening audience of thinking people in all countries. War-literature is always popular, but it is beginning to be

seen that there are wars of opinion and conflicts of ideas carried on in the intellectual world which have at least an equal interest with the narratives of military campaigns and the records of carnage on fields of battle.

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It is but an act of justice to Dr. Deems, of this city, to state that he replied to the article of Mr. Boyd in the June Monthly, entitled "Science and the Logicians." We were compelled to decline publishing the reply to cut off a controversy that would have consumed more space than we can allow to such discussions.

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## LITERARY NOTICES.

The Five Senses of Man. By Julius Bernstein, Professor of Physiology in the University of Halle. With Numerous Illustrations. No. XXI. of the "International Scientific Series." Pp. 304.

The work intrusted to the accomplished Professor of Physiology at Halle, Dr. Bernstein, has been admirably performed. Aware of the importance of his undertaking, and that his work would promptly reappear in all civilized countries, the author has taken his time, and produced a volume second to none in the series to which it belongs, and which will be valued as an able and permanent contribution to physiological literature. Many works have appeared upon this general subject, of varied merit, but they have generally been more anatomical than physiological, and have dealt rather with the mechanism of sensation than with its processes and philosophy. Prof. Wilson's book, published several years ago, was a pleasant piece of rhetorical work, but wholly inadequate as a scientific discussion of the subject, even at that time. Dr. Bernstein has taken up the problem of the senses of man from the latest point of view reached by physiology and psychology, and, while very full and clear in his description of the instruments and apparatus of sensation, the strength of his book and its more especial claim to attention will be found in the lucid analysis which he gives of what may be called the psychical aspect of sense-activity. He views the senses as the biological gateways where impressions from the external world pass into the organism, and are transformed, through the wonderful endowments of the nervous system, into consciousness in the mental sphere. This is unquestionably the profoundest mystery in the realm of life, and the ultimate *how* of this transformation will probably forever remain one of Nature's impenetrable secrets. But all ultimate explanations are beyond the grasp of science, which completes its work when it has analyzed and established the conditions of phenomena. No doubt it would be interesting to solve the ultimate problems of Nature, were such a thing possible to the human mind, but it is only of importance to find out that which is capable of being known. Even this field is inexhaustible, and whatever explanation may be reached we are never certain that a deeper explanation is not still attainable. In this matter of the nature and operation of the senses great progress has recently been made, and physics, chemistry, physiology, histology, and psychology, have all contributed their separate rays to the illumination of the subject. Many points are unsettled, and many perplexities and obscurities remain to be cleared up; but there has still been an immense amount of efficient and successful work of research that required to be digested by some master-hand so as to be available for the common reader who has no time to master elaborate scientific treatises. It was not an easy thing to find a man competent, interested, and willing to undertake this task; but it fortunately fell into the right hands. Dr. Bernstein has proved himself to be not only possessed of the requisite knowledge, but to be an adept in the art of presenting it, as will be seen by the extract from his work given in the present number of the Monthly. He had a reputaion as a clear and skillful writer, which the present volume will enhance; while the translation does him justice, and presents his exposition in an attractive English form. This volume is one that might be well adopted as a text-book for our schools.

SIMILARITIES OF PHYSICAL AND RELIGIOUS KNOWLEDGE. By JAMES THOMPSON BIXBY. Pp. 266. New York: D. Appleton & Co. Price, $1.50.

OUR readers will be interested in the article on "Religion and Science as Allies," by Mr. J. T. Bixby. This gentleman is author of the volume under the foregoing title—a work written in a liberal spirit, with much discrimination and judicial fairness, and which aims to get down to the radical harmonies of religion and science. There is a steadily-deepening interest in the thinking world on the question of the relations of these two subjects which relates to both their analytical and historical aspects. Mr. Bixby's book is one of the best representatives of a large class of works that are devoted to working out the fundamental relations of science and religion. The inquiry goes deep, and still involves the most radical disagreements among thinkers of different schools. Partial views must still be expected while thinkers remain partisans, for current scholarship is not yet broad enough to deal with a problem so comprehensive in a thoroughly synthetic and unifying way. But there is compensation from the number of earnest and vigorous minds that are taking it up on its various sides, and, from the thorough sifting which the subject will thus receive, we may expect a wider agreement and more pacific relations among the parties interested. The present work is written in the interest of peace, but the author does not shirk its difficulties, and is aware how large must be the mutual concessions before lasting concord can be gained. He is an independent thinker, who has studied carefully the later products of scientific literature, and treats them with marked critical ability. The volume is full of instruction, well presented, and we cordially recommend it to readers interested in this line of inquiry.

THE SCIENTIFIC BASES OF FAITH. By JOSEPH JOHN MURPHY, author of "Habit and Intelligence." Pp. xliv–474. 8vo. London: Macmillan & Co. 1873. Price $5.00.

WE regard this work as of unusual interest and value, and taken in connection with its predecessor, "Habit and Intelligence," it should be welcomed by those who desire a more harmonious adjustment of the relations among the thinkers and believers (often coexistent in the same person) of the present time. It is an attempt to "harmonize Scripture with science," that is say, to "try by how little distortion of the sense of Scripture, and by how little misrepresentation of the facts of science, the narratives of the Old Testament may be made to coincide with the facts disclosed by scientific research." Through twenty-nine chapters, with an "introduction" and a "conclusion," Mr. Murphy discusses such subjects as the relations of "Metaphysical and Positive Philosophy," "The Metaphysical Interpretation of Nature," "The Bases of Knowledge," "The Limits of our Knowledge," "The Proof of Deity from Intelligence and Design," "The Structure of the Universe," "Nature and the Religious Sense," "Immortality," "The Relation of History to Religion."

The author is, we believe, a clergyman of the lately disestablished Church of Ireland, and his views of Scripture inspiration and interpretation may fairly be called "broad," as that word is now understood in the English Church; but we rarely find a man who seems more reverent in spirit: courteous, critical, and fair, he is worthy of a patient, candid hearing, alike from those who hold very "conservative" views of the Bible and of orthodoxy on the one hand, and on the other from those who are inclined to think that the "age of faith" has passed away before the more certain and substantial things of the "age of science."

Mr. Murphy asserts it to be "as certain as history and philosophy can make it that science is absolutely independent of theology;" yet he insists that science and faith are closely related, and that no treaty of peace can be established on the assumption that they have nothing to do with each other. His view of their mutual relation is illustrated by reference to that between *matter and life*, and *life and mind*, *life* presupposing *matter* as its *basis*, *mind* presupposing *life* as its *basis*. So *science* (using the word in its largest meaning and application) is presupposed as the *basis of religion*, which he believes will ultimately be recognized as the summit and crown of all knowledge.

His plea for the validity and value of consciousness as a *base* of knowledge, and his demand for a place for the *metaphysical* method coördinate with the *inductive*, are suggestive and able. Belief in the past, trust in the reality of memory, in personal identity, in the uniformity of the order of Nature, and in an external world, is *metaphysical*—is made known by consciousness only, and is of the nature of faith.

We are reminded here from time to time, as we read, of Bixby's lately-published work on "Similarities of Physical and Religious Knowledge," but we have no space to attempt even an approach to a complete synopsis of the work, and must commend it to the personal examination of those interested.

HAY-FEVER; OR, SUMMER CATARRH: its Nature and Treatment: Including the Early Form, or "Rose Cold;" the Later Form, or "Autumnal Catarrh;" and a Middle Form, or "July Cold," hitherto undescribed; based on Original Researches and Observations, and containing Statistics and Details of Several Hundred Cases. By GEO. M. BEARD, A. M., M. D., Fellow of the New York Academy of Medicine, etc. New York: Harpers. Pp. 266. Price, $2.00.

THIS is a painstaking book, that will hardly fail to prove instructive to the class of sufferers for whose benefit it has been prepared. Dr. Beard has supplemented his medical observations and experience of the disease, which he says is incorrectly termed "Hay-Fever," by an extensive series of inquiries put to patients in regard to numerous facts which it seemed impossible to get in any other way. He sent a circular containing fifty-five questions to a large number of persons, and received reports of some two hundred cases, giving much valuable information; and this, with his considerable personal practice, is made the basis of his treatment of the subject. In regard to the nature of the malady, he observes in the preface:

"The theory taught in this book, that this disease is a complex resultant of a nervous system especially sensitive in this direction, acted upon by the enervating influence of heat, and by one or several of a large number of vegetable and other irritants, has the advantage over other theories that it accounts for all the phenomena exhibited by the disease in this or in any other country.

"The transmissibility of the disease from parents to children; the temperaments of the subjects; the capricious interchanging of the early, the middle, and the later forms; the periodicity and persistence of the attacks, and their paroxysmal character; the points of resemblance between the symptoms and those of ordinary asthma; the strange idiosyncrasies of different individuals in relation to the different irritants; the fact that it is a modern disease, peculiar to civilization; the fact that it abounds where functional nervous disorders are most frequent, and is apparently on the increase *pari passu* with other nervous diseases; and, finally, the fact that it is best relieved by those remedies that act on the nervous system—all these otherwise opposing and inconsistent phenomena are by this hypothesis fully harmonized. Those, however, who are unwilling to accept this interpretation will in this work find a *résumé* that is meant to be both impartial and exhaustive of other theories, and of all known facts relating to this affection, wherever observed. . . . Bearing in mind that this work will find its readers mostly among the laity, and chiefly among the sufferers from the disease, the aim has been to avoid, so far as might be, purely technical words and phrases, and, while keeping strictly within the limits of science, to bring every point within the comprehension of those who know little or nothing of medicine, save what has been wrought into them by their own painful experiences with this distressing malady."

REPORT ON THE HYGIENE OF THE UNITED STATES ARMY, WITH DESCRIPTIONS OF MILITARY POSTS. By JOHN S. BILLINGS, Assistant Surgeon, U. S. A. Washington: Government Printing-Office. 1875. Pp. 567.

THE author begins his report with an allusion to the difficulty experienced by army medical men in getting their recommendations on sanitary matters attended to by the officers in charge of the posts, and follows this with the order of 1874, defining the duties of the medical officer so far as they relate to the hygienic management of the soldiers. This order seems broad

enough for all practical purposes, and, could the officers be got to coöperate in carrying out its provisions, the result would undoubtedly be a material lessening of disease and mortality in the army. But, as now managed, both disease and mortality are largely in excess of what they should be. From a table showing the ratio per thousand of mortality in the United States Army as compared with the mortality of males between twenty and forty years of age in civil life, it appears that the death-rate from disease among the soldiers is from twice to three times as great per thousand as among civilians. The author ascribes this partly to the character of the food, which is often deficient in fresh vegetables, but mainly to the habitations in which the soldiers are obliged to live. In many instances these are without provision for ventilation, are often much overcrowded, and are rarely furnished with adequate appliances for bathing and the maintenance of cleanliness of person. In the matters of clothing and hospital service the author considers the troops generally well provided for. The bulk of the report is taken up with descriptions of military posts, furnished by different members of the army medical corps.

EIGHTH ANNUAL REPORT ON THE NOXIOUS, BENEFICIAL, AND OTHER INSECTS OF MISSOURI. By C. V. RILEY, State Entomologist. Pp. 196. Jefferson City: Regan & Carter print.

THE noxious insects considered in this volume are the Colorado potato-beetle, canker-worm, army-worm, Rocky Mountain locust, and the grape phylloxera. One innoxious insect, the yucca-borer, is treated of. The loss sustained in the State of Missouri in 1875 from injury done to grains alone by the Rocky Mountain locust is estimated by Prof. Riley at $15,000,000. Accordingly, we are not surprised that the greater part of the annual report should be devoted to this insect. Several interesting questions regarding the natural history of the locust are discussed, such as its transformations, the habits of the unfledged locusts, the directions in which the young locusts travel, etc. It has been asserted that young locusts are led in their marches by "kings" or "queens," but this Prof. Riley declares to be an error. "Certain large locusts," he writes, "belonging to the genera *Acridinia* and *Œdipus* hibernate in the full-grown, winged state, and not in the egg-state, like the Rocky Mountain species always with us; their presence was simply more manifest last spring, when the face of the earth was bare. Hopping with the others, or falling into ditches with them, they gave rise to this false notion, and it is an interesting fact, as showing how the same circumstances at times give rise to similar erroneous ideas in widely-separate parts of the world, that the same idea prevails in parts of Europe and Asia."

THE GEOLOGICAL AGENCY OF LATERAL PRESSURE EXHIBITED BY CERTAIN MOVEMENTS OF ROCKS. By W. H. NILES. Pp. 15. Boston: Kingman print.

PROF. NILES has studied, in five different localities, the evidences proving the continued action of the lateral pressure occasioned by the earth's contraction. His general conclusions are 1.—That the rock at these localities has been brought into a compressed condition by a powerful lateral pressure, acting only in a northerly and southerly direction; and, 2. That, when opportunity is presented, the compressed rock expands with great energy.

GEOGRAPHICAL VARIATION AMONG NORTH AMERICAN MAMMALS. Also, Sexual, Individual, and Geographical Variation in *Leucosticte tephrocotis*. By J. A. ALLEN. Pp. 41. Washington: Government Printing-Office.

MR. ALLEN finds the variation in size, with latitude, to be surprisingly great in wolves and foxes, amounting in some species to twenty-five per cent. of the average size of the species, while in other species of the *Feræ* it is almost *nil*. Contrary to the general impression, the variation in size among representatives of the same species is not always a decrease with the decrease of the latitude of the locality, but is in some cases exactly the reverse.

TRANSACTIONS OF THE KANSAS STATE HORTICULTURAL SOCIETY (1875). Pp. 277. Topeka: G. W. Martin print.

THE State Horticultural Society of Kansas appears to be a very industrious and efficient body. Two meetings were held during the year 1875, and the proceedings

are here fully reported. An important feature of the volume before us is the reports of the county vice-presidents. These officers are charged with the duty of organizing local horticultural societies, and of reporting annually to the society upon horticultural matters in their localities.

THE CONSTANTS OF NATURE. By F. W. CLARKE, S. B. Washington: The Smithsonian Institution.

IN 1873 the Smithsonian Institution published Part I. of the above-named work, and we have now before us Parts II. and III., as also a first supplement to Part I. In this first part are given tables of specific gravities, boiling-points, and melting-points. Part II. is a table of specific heats for solids and liquids, and Part III. gives tables of expansion by heat for solids and liquids. In compiling these tables Prof. Clarke has expended a vast amount of labor—a labor of love, inasmuch as his services are rendered gratuitously.

ARCHIVOS DO MUSEU NACIONAL DO RIO DE JANEIRO. Rio de Janeiro: Imprensa Industrial. Pp. 30, quarto, with Plates.

THE *Archivos* is published quarterly, and is the organ of the National Museum of Brazil. Its first object is to give an account of the contributions to science made by that institution, but it will also from time to time contain essays on scientific subjects from other sources. In the present number (which is the first) there are three articles, viz.: "Studies of the Shell-heaps (*Sambaquis*) of Southern Brazil," by Carlos Wiener; "On Some *Tangas*" (well translated "fig-leaves" in the *Nation*) "of Baked Clay used by the Ancient Inhabitants of the Island of Marajó," by Ch. Fred. Hartt; and "Studies upon the Morphological Evolution of the Tissues in Sarmentose Caules," by Ladislau Netto.

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## PUBLICATIONS RECEIVED.

The Kinematics of Machinery. By F. Reuleaux. Pp. 638. New York: Macmillan. Price, $7.50.

Elements of Latin Grammar. By G. Fischer, LL. D. Pp. 236. New York: Schermerhorn. Price, $1.25.

Forest Culture and Eucalyptus-Trees. By E. Cooper. Pp. 237. San Francisco: Cubery & Co.

Exploring Expedition from Santa Fé to the Junction of Grand and Green Rivers. By J. S. Newberry. Pp. 148. With Plates. Washington: Government Printing Office.

First Steps in Political Economy. By M. R. Leverson, Ph. D. Pp. 215. New York: Authors' Publishing Co. Price, $1.25.

The Ultimate Generalization. Pp. 56. New York: Somerby.

Chorea. By G. T. Stevens, M. D. Pp. 19. New York: Appletons.

The Study of Music. By E. B. Oliver. Pp. 10. Hartford: Case, Lockwood & Brainard.

Plastic Dressing in Fractures of Lower Extremity. By D. W. Yandell, M. D. Pp. 10. Indianapolis: *Journal* print.

Physiology of the Respiratory Apparatus. By J. Ott, M. D. Pp. 4. Chicago: Kissell & Co.

Guide to the Museum of the Academy of Natural Sciences of Philadelphia. Pp. 128.

Report on the Retreat for the Insane. Pp. 36. Hartford: Case, Lockwood & Brainard.

Cast-Steel Works of Frederick Krupp. Pp. 20. Published from 15 Gold Street, New York.

A Life-Zone in Space. By W. H. Gregg, M. D. Pp. 5. Elmira, New York: Watts print.

Building Associations. Pp. 29. Philadelphia: Social Science Association.

Explorations of Mounds near Davenport, Iowa. By R. J. Farquharson, M. D. Pp. 18. With Plates. Salem (Mass.): *Press*.

Modern Languages and the Higher Education. By E. S. Joynes. Pp. 12. Louisville: J. P. Morton print.

Mask of Comus. Edited by H. B. Sprague, A. M. Pp. 35. New York: Schermerhorn.

English Grammar. By S. W. Whitney, A. M. Pp. 160. New York: Schermerhorn.

On Life. By E. C. Seaman. Pp. 15.

Report on the State Lunatic Asylum. Pp. 72. Albany: Weed, Parsons & Co. print.

American Shakespeare Bibliography. By K. Knortz. Pp. 16. Boston: Schoenhof & Moeller.

The State and Primary Education. By R. D. Allen. Pp. 7. St. Louis: Ware & Co.

Animal Resources of the United States. By G. B. Goode, M. A. Pp. 126. Washington: Government Printing-Office.

Human Rights and the Natural Laws of Marriage. By G. J. Ziegler, M. D. Pp. 263. Philadelphia: The Author.

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## MISCELLANY.

**A Preliminary Note on Menopoma Alleghaniense of Harlan.**—At the Buffalo meeting of the American Association for the Advancement of Science, Prof. A. R. Grote read a paper with the above title on the *Menopoma*, an aquatic salamander, with soft, leathery, scaleless skin, inhabiting the tributaries of the Mississippi River. After the examination of a large number of specimens, the characters separating the species *Menopoma Alleghaniense* and *fuscum*, as recently accepted by Cope, were found inconstant, and Grote comes to the conclusion that "there is only *one* and not *two* species inhabiting the water-shed of the Mississippi." After watching the habits of the animals in the aquarium, Grote succeeded in ascertaining the fact that the outer layer of the skin is shed as in snakes and toads, and is, in some cases at least, swallowed by the animal, since it was in one instance taken out of the mouth of the specimen. Grote succeeded in obtaining eggs laid on August 30th, and draws attention to the fact that the *Menopoma* puts on a "marriage-dress" during this period of its life, the tail broadening, and a plaited extension of the skin appearing along the sides of the body. The habits of the *Menopoma* seem to be nocturnal, and its eggs are laid along the muddy banks of the streams it frequents. The egg contains a yolk about the size of a pea floating in a glairy white fluid, surrounded by a membrane like that enveloping the albumen in a bird's-egg, and taking in a certain amount of water by endosmosis.

**Insect Parasites in Muddy Trout-Ponds.**—In the fall of 1873 the owner of a pond near Amsterdam, in this State, put into the pond some yearling trout. About the middle of last July a few dead fish were seen floating upon the water. On the tail of one of these dead fish was found "a very curious green bug, about the size of a pumpkin-seed; long legs, red eyes, and a long stinger." Hereupon the owner of the pond consulted Mr. Seth Green, and the latter expressed his belief that the insects were destroying the trout. "The cause is," he writes, "that you have no quick-running water, like a creek, with gravel bottom, running in your pond. By having such a place, when any insect is fastened on a trout, he will go to the quick-running water, and will soon rub it off. Putting trout in a pond with mud and weedy bottom that contains water-insects, and no stream flowing into it, is like tying a man's hands and placing him

where there are plenty of mosquitoes, gnats, and black flies. The running water and gravelly bottom answer the same purpose in keeping the trout free from insects as our hands do in keeping the mosquitoes from us."

**Management of the Bedding in Sleeping-Cars.**—A writer in the *Sanitary Journal*, of Toronto, calls public attention to a source of danger existing in the sleeping-arrangements of certain railway-carriages. The beds in each section are opened out at night, after having been tightly closed for a period of twelve or fourteen hours. "Into these beds," says the author, "a stranger enters, probably partially recovered from some infectious disease, such as small-pox, scarlet fever, etc. He makes his exit, and at once these beds are closed and fastened down carefully again until the following night, when the same process of bed-making is observed, with a change of sheeting, as the case may be." The remedy suggested by the author does not appear to be sufficient: it consists simply of perforations in the bed-casings, with openings outward, so as not to communicate with the interior of the coach. But, if by this plan the germs of contagious disease are not destroyed, the bedding at least will be aired to some extent, and this will be no slight advantage.

**A Neglected Naturalist.**—Under the title of "A Neglected Naturalist," Mr. H. E. Copeland contributes to the *American Naturalist* a vindication of Constantine S. Rafinesque against the aspersions cast upon his scientific work by European and American critics. It is charged that the work done by Rafinesque only introduced confusion into botany and zoölogy by needlessly multiplying genera and species. But, according to the author, "thirteen genera, eight sub-genera, and sixteen species of the plants referred to in Gray's manual, are his. His writings on conchology have been considered worth editing by Binney and Tryon. Of our reptiles and batrachians four genera and six species bear his name. He described four genera and four species that are retained in the current literature treating of our mammals. The genus *Helmitherus* of birds was proposed by him." In 1820 Rafinesque published a "Natural History of the Fishes of the Ohio River." Mr. Copeland declares himself to be profoundly impressed by the accuracy of the work of Rafinesque as represented by this little volume. Of seventy-nine genera and one hundred and fifteen species of fishes known as inhabiting the Ohio and its tributaries twenty-nine genera and thirty-seven species were first described by this neglected naturalist, and the eliminating of seasonal and sexual forms from the rank of species, and the identifying of more of his genera on a better acquaintance with the fishes of the Ohio, will constantly make the ratio greater.

**Marsh-Water as a Vehicle of Ague-Poison.**—In his volume on "Practical Hygiene" the late Dr. Parkes adduces a number of facts to show that marsh-water is a vehicle of ague-poison. The more commonly-received opinion, however, is that the air of marshes is the sole cause of intermittent fevers. Certain observations made at Tilbury Fort, on the river Thames, appear to confirm Dr. Parkes's view. In the "Army Medical Blue-Book" it is stated that the troops at Tilbury Fort are supplied with water collected on the roofs of buildings, and stored in underground tanks at or below high-water mark. The officials at the neighboring railroad-station use spring-water pumped from a well. Now ague has, for a long time, been common among the troops at Tilbury Fort, and almost unknown at the railroad-station. During some cleansing and repairs to the tanks, spring-water was obtained from the latter source for several months together, during which time ague disappeared from among the soldiers at Tilbury, but on the tank-water being again brought into use, cases of ague again made their appearance, the disease ceasing on discontinuing that source of supply. Samples of water from these different sources were submitted to chemical analysis, when it was found that the amount of organic matter in the tank water was greatly in excess of that in the spring (railway-station) water, while the presence of vegetable and fungoid matter made it evident that there had been soakage of water from the surrounding marsh into the tanks.

**Dry Thunder-Storms.**—A correspondent in Oregon, Missouri, communicates some observations on weather phenomena, especially upon the influence of forests on rainfall. "When the earth has become dry, parched, and very warm, on occasion of thunder-storms, I have often," he writes, "noticed for hours, while it was thundering overhead, the mist, falling from the storm-clouds, to roll back, after nearly reaching the earth, in the form of lighter vapor. I think this rain, or mist, in falling, passed down to the stratum of very hot air on the earth's surface, and became a steam, large volumes of white vapor forming suddenly and rolling back and up. Now I am confident that, if the earth had been shaded by trees, this rain would have fallen on the ground.

"This phenomenon can be seen here every hot, dry season. It has, no doubt, escaped the attention of all but very close observers. Mine was called to it by a question asked while one of these dry thunder-storms was prevailing—a common thing—dry thunder-storms—thunder rattling overhead, but not a drop of rain falling. The white mist is not easily observed overhead, where all is light; but opposite to the sun, under the dark storm-cloud, it is very plain, and must attract attention."

**Fertilization of Plants.**—Mr. Thomas Meehan discovers in the "sleep" of plants an agent in their self-fertilization. The fertilization of the common *Claytonia Virginica* had been somewhat of a mystery to him, as, in view of the prevailing theory of cross-fertilization by insect agency, this plant ought not to be a self-fertilizer; but from repeated observation he was satisfied that no insects had visited plants that had yet seeded abundantly. Watching the process of fertilization, he found that the stamens on expanding fell back on the petals expanded during daylight. At night, when the flower closed, the petals drew the anthers up in close contact with the pistils. Cross-fertilization could be accomplished by insects if they visited the flower, but they did not, and actual fertilization only occurred in this way. In many cases, especially late in the season, the stamens recurve so much as to be in a measure doubled up by the nocturnal motion of the petals. The anthers were not drawn into contact with the stigmas in these cases, and, as a result, the flowers were barren.

In the *Ranunculus bulbosus*, our common buttercup, in the evening following the first day's expansion of the young flower, the immature anthers and the young stigmas would be found covered with pollen-grains. The inference would generally be, that this had been carried there by insects. But, as he had been especially on the lookout for insects as visitors to the buttercup, and feeling sure that none of any consequence had been to them, he examined these flowers carefully, and found that, on the first expansion of the flower, a single outer series of stamens burst their anther-cells simultaneously with the expansion of the flower, and, by contracting the cell-walls, ejected the pollen to the smooth petals, from which it easily fell to the immature anthers and stigmas, when the flower closed for the night.

Knowing that another species of buttercup, the *Ranunculus abortivus*, had fixed spreading petals which did not close at night, and which, though with comparatively large nectariferous glands full of a liquid secretion, was wholly neglected by insects, and yet had every flower seeding profusely, he was anxious to find, in view of his other discoveries, how these were fertilized. Visiting a wood after twilight, to ascertain if any nocturnal insects visited them, he found that, though the petals did not close at sundown, the slender pedicles drooped, inverting the flower, and in this way the pollen found its way from the petals to the stigmas without any difficulty whatever.

**Functions of the Root-Hairs of Plants.**—In an article published in the *Gardener's Monthly*, Prof. B. C. Halsted points out the functions of the "root-hairs" of plants. These so-called root-hairs are thread-like structures, consisting of elongated surface-cells of the root. These hairs absorb water out of the soil either by capillary attraction, or by the process of diffusion, or by osmotic action. It is a well-known fact that porous bodies absorb liquids to a greater or less extent. A dry cloth hung so that one

corner will dip into water soon becomes saturated. This is capillary attraction, and has a place in root-absorption. From an extended study of the properties of liquids, the law of diffusion has been established, viz., that when two or more miscible liquids of different densities are placed in contact, interchange will take place till the whole liquid is homogeneous. This property of liquids will account for the movement of the absorbed sap to any part of the same cell—from the tip of the hair to its base. But there is another kind of diffusion—*osmose*, or membrane diffusion. When liquids of different densities are separated by a thin membrane, diffusion takes place through this partition with a rapidity depending on the nature of the liquids and membrane, the greater flow being toward the denser fluid. The cell-wall of a root-hair is such a membrane, separating the denser liquid within the cell from the thinner one without; and, as this membrane is a living, growing one, it may be specially effective for osmotic action. From the function, position, and delicate structure of the root-hairs, at least one important practical conclusion can be drawn, viz., the importance of preserving them when a plant is to be potted or transplanted.

**The Philosophy of Dreams.**—Prof. Ferrier recently delivered, at the London Institution, a lecture on "Dreaming," explaining its phenomena by the results of his famous experiments on the localization of faculties in the brain. For each class of impressions there are, he said, special regions of consciousness in the brain. The impressions received are photographed on the brain, and are capable of being revived. But for this power of recalling them no knowledge would be possible. Memory, or the registration of sense-impressions, is the ultimate basis of all our mental furniture. Each piece of that furniture has its function, like the letters in a compositor's case. We have a sight-memory, a hearing-memory, etc. When thinking, or engaged in ideation, we are but recalling, as shown by Herbert Spencer and Bain, our original sensations and acts of cognition. Commonly the reproduction is very faint, but in some instances it is nearly or quite as vivid as the original sensation. This is especially true of poets, painters, religious enthusiasts, and others. Those portions of the brain which are most continuously in action during waking-hours require the longest rest during the hours of sleep. Hence the centres of attention would sleep while the functions allied to reflex actions would more easily waken.

The brain in sleep Prof. Ferrier compared to a calm pool, in which a stone causes ripples, liable to interruption by other ripples similarly caused. So the ripples of ideation get confused. But, again, the circle on the pool may not be interrupted, and then the ideation will be regular. The current of ideation may be coherent or incoherent. The most vivid association, which is commonly the latest, dominates over the rest. Dr. Reid, the metaphysician, once dreamed of being scalped—there was a blister upon his head. Dr. Gregory, from having a bottle of hot water at his feet, dreamed of walking up the crater of Etna. Visceral conditions are the most frequent sources of dreams; the hungry dream of feasts, the thirsty of water, the dropsical of drowning. Dr. Ferrier happily compares incoherent dreaming to the changes in a kaleidoscope. There is nothing new in dreams; the blind do not dream that they see, nor the deaf of music. In such cases there is a letter missing from the font of type. Our fancy is awake during dreams, and the faculties which should check it are asleep. Hence it is that nothing surprises us in dreaming.

**Locusts in Africa.**—In his work, "The Victoria Falls of the Zambezi," Eduard Mohr gives an impressive description of a flight of locusts witnessed by him in the region of the Vaal River. "I noticed," he writes, "on the western horizon what I took to be columns of smoke, rising higher and higher until they reached the zenith. I thought the bush must have been set on fire, for the whole of the horizon from the northwest to the southeast was already apparently enveloped in clouds of smoke. This, however, was caused by no fire, but by locusts. Presently a few, then dozens, then hundreds, then thousands, of locusts fell upon us, coming down in such heavy

showers that the air was darkened with them; and through the whizzing, whirling veil they flung about us we could look with the naked eye at the sun, which, although high in the heavens, had the blood-red, rayless appearance usually peculiar to the time of setting." He adds that the natives, with their horses and cattle, as well as elephants and other wild ruminants, feed on them greedily; the author found them perfectly tasteless.

**Natural History in New Guinea.**—The Italian naturalist, D'Albertis, continues his explorations and studies of natural history in the island of New Guinea. He recently made the ascent of a mountain 1,200 feet high, on Yule Island, obtaining a good view of the plains watered by the Amama River. This river D'Albertis has partly ascended on several occasions; he states that it traverses an extensive and fertile district well suited for grazing. The Nicura River, into which the Amama debouches, is bordered by mangroves, eucalyptus, grass-trees, etc. He remarks that the natives appear everywhere ignorant of the uses of metals; and he is of opinion that Wallace and others are right in recognizing the existence of two races in the island. The aborigines he considers are confined to the western and interior portions, while the inhabitants in the other parts represent a taller, lighter-colored, and more intelligent race, which displaced the older tenants.

**Sulphide of Carbon as an Insect de.**—The use of carbon sulphide is recommended by J. B. Schnetzler, of the Lausanne Academy, as a means of destroying the insects which infest herbaria and entomological collections. The Academy collection of Swiss flowering-plants having been attacked by *Anobium paniceum*, M. Schnetzler had a wooden box made large enough to contain five fasciculi of the herbarium, each composed of about 200 plants. Four ounces of carbon sulphide were poured into the five fasciculi; the box was tightly closed, and the whole left for a month. All the insects were destroyed, and no injury was done to the specimens, or to the papers to which they were fastened. The expense of the operation is very small. M. Schnetzler recommends that the boxes should be placed under a shed, as in case of the escape of vapor there might be danger of explosion. The same process may be employed for collections of insects.

## NOTES.

During the present year the United States Fish Commission have placed in the Hudson River 4,580,000 young shad. The commissioners observe a steady increase in the supply of this fish. They ask, however, for legislation compelling a cessation of fishing on Sunday.

At the distance of 20 miles from Carter Station, on the Union Pacific Railway, is situated a remarkable coal-mine. It is about 4 miles in length, and consists of 16 veins, lying one above another, with a thin layer of sandstone intervening. The bottom vein is the thinnest (5 feet), while the one next above is over 75 feet in thickness. A few feet above this is a vein of 60 feet, another of 40 succeeding, and so on, making in all about 400 feet of coal. The veins slope at an angle of about 22°, and are very easy of access.

Prof. Riley, at a meeting of the St. Louis Academy of Science, exhibited a Colorado potato-beetle, which was so completely covered with a mite parasite that the point of a needle could not be placed on any part of the beetle's body without touching one of the parasites. He estimated the number of mites at 800, and they had killed the beetle. Aside from the toad and other reptiles, the crow, the rose-breasted grossbeak, and domestic fowls, among birds which prey on the *Doryphora decemlineata*, Prof. Riley had in his report figured or described no less than 23 insect-enemies that attack and kill it. Only one of these is a true parasite, and this mite makes the second. It belongs to the family *Gamasidæ*.

At a meeting held in London, in aid of the fund for a memorial to the late Dr. Parkes, a resolution was adopted which declared it desirable that the memorial should take the form of a museum of hygiene. A list of subscriptions was read amounting to £675.

Everywhere in Germany carrier-pigeons are being trained for service in time of war, to keep up communication between the garrisons of besieged fortresses and the military authorities. Another use of these pigeons is suggested, viz., as a means of conveying intelligence from light-ships to the nearest port, in case the former are in need of succor.

THE London publisher, Murray, announces a new work by Mr. Darwin, entitled "The Results of Cross and Self Fertilization in the Vegetable Kingdom."

BY subcutaneously injecting into animals concentrated solutions of sodic lactate, Preyer produces in them a state apparently identical with normal sleep. This confirms the theory which attributes the drowsiness caused by fatigue to the presence in the blood of certain compounds (as lactic acid) produced by the disintegration of nervous and muscular tissue.

SOME curious statistics illustrating the liability of the eye to injury have been compiled by Drs. Zander and Geissler. They assume that the mean superficies of the human body is about fifteen square feet, and that the mean superficies of the orbital opening is about 180 square lines, from which it should follow, if all parts were equally exposed to injury, that lesions of the eye would bear to lesions of other parts of the body the proportion of about one in 600. As a matter of fact, the actual proportion is more than twenty times as great, or about 36 in 1,000.

IT has been shown by experiment that Prussian blue in oil is the most stable of pigment colors. Aniline colors, on the contrary, are the most fleeting; indeed, they are unsuitable for use by the painter. Photographs tinted with aniline colors soon lose their tints, and the colors are often seen fading while the pictures are yet exposed for sale.

M. LECOQ DE BOISBAUDRAN, the discoverer of gallium, has succeeded in reducing to the metallic state about ten centigrammes of the new metal. When pure, gallium melts at the very low temperature of 85° Fahr. It adheres readily to glass, forming a whiter mirror than mercury, but its low fusion temperature makes it practically useless for this purpose. It oxidizes very slightly when heated to redness, but does not volatilize.

A PATIENT in the Royal Infirmary, Edinburgh, who suffered from cancer of the tongue, had the organ amputated, except about half an inch. The operation was successful and the patient now speaks quite distinctly; in doing so he seems to tilt upward and forward both the hyoid bone and the larynx.

AT the National Glass Company's works, Bellaire, Ohio, lamp-chimneys are made by a process resembling that of De la Bastie. A local newspaper writer mentions having seen an eightpenny-nail driven through a board an inch and a half thick with one of these chimneys of hardened glass.

THE nickel-mine near Lancaster, Pennsylvania, yields about 6,000 tons of ore per year. Eleven shafts have now been sunk, ranging from 110 to 140 feet in depth, and connected by tunnels underneath. The number of men employed at the mine is 200.

CARBON occurs in the heavenly bodies in three forms, according to Prof. J. Lawrence Smith, viz.: the gaseous form, as detected by the spectroscope in the attenuated matter of comets; the solid form, impalpable in its nature and diffused in small quantities through pulverulent masses of mineral matter that come to the earth from celestial regions; and the solid form, compact and hard, resembling graphite, and this is imbedded in metallic matter that comes from regions in space. It is not necessary to assume that this cosmical carbon has an organic origin.

A PRIZE of five hundred francs has been offered by M. Paul Bert for the best means of protecting the lives of aëronants and mountain-climbers in circumstances where cold and rarefied air become dangerous. His prize is open to competition till the last day of the present year.

A FIREMAN'S suit, invented by a Swede named Oestberg, is made in two layers, the inner one of India-rubber, the outer one of leather, the head being protected by a helmet resembling that worn by divers. At the girdle is fixed a piece of hose, which serves both for air and water. The air-pipe, fed from two blowers, is placed inside the water-pipe, and brings the air, after being cooled by the surrounding water, into the inner part of the dress. The air inflates the costume, passing away through the two small openings made for eye-pieces. The current of air not only keeps the inclosed body cool, but drives smoke and flame away from the eyes. At the back the water-pipe divides, one branch serving as an extinguisher, the other passing into the outer coating of the dress, the stream being distributed over the whole outer surface. With the apparatus on, the inventor stood in the middle of a pile of burning shavings and logs without taking the least harm.

AN epidemic resembling cholera appeared among the cats in Delhi last year. The disease was not known to extend beyond the walls of the city, nor was it confined to any quarter. It gradually declined, and fully disappeared about September 20th, although the cholera did not cease till near the end of November. The number of cats carried off by the disease was estimated at 500. The symptoms were in almost every respect identical with those of cholera. Experiments were made with cholera-virus, which was found to communicate an analogous disease to the cats.

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